MEDITERRANEAN JOURNAL FOR RESEARCH IN MATHEMATICS EDUCATION

AN INTERNATIONAL JOURNAL

Volume 16. 2019

CYPRUS MATHEMATICAL SOCIETY
ΚΥΠΡΙΑΚΗ ΜΑΘΗΜΑΤΙΚΗ ΕΤΑΙΡΕΙΑ
Nicosia - Cyprus

Editor
Gregoris Makrides

Mediterranean Journal for Research in Mathematics Education

An International Journal
of Cyprus Mathematical Society

ISSN 1450-1104 Cyprus Mathematical Society

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Mediterranean Journal for
Research in Mathematics Education
Vol. 16, 7-18, 2019

Primary Teachers' Teaching Practices in Mathematics and Science Classes. A descriptive Research Approach.

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Abstract

In 5th and 6th Grade Mathematics and Physics classes, 320 45-minute sessions (160 in each subject) were observed in Greek Primary Schools. The observations aimed to identify: a) the use of learner-centered and teacher-centered teaching approaches b) the nature of dialogue between pupils and teachers and c) what manipulatives or artifacts (either conventional or technologically oriented), the teacher uses to achieve the learning outcomes. In particular, the following 11 dimensions - (Teacher Lecture, Lecture with pre- designed material, Lecture with hands-on material, Lecture with Demonstration, Lecture with Questioning, Team Work, Desk-Work, Classroom Discourse, use of Multimedia, Pupils' Presentations and Pupils' Play) - were recorded according to the Teaching Dimensions Observation Protocol (TDOP), (Hora, 2015). The TDOP is a descriptive protocol aiming to provide direct information about how instruction is done, and it focuses on noting down the time of dimension codes and traits. Findings show that, overall, primary teachers use various teaching practices. However, the Teacher -Centered Instruction and the Teachers' Questioning are more frequently used, both, in Mathematics and Science classes. Moreover, no statistically significant difference was found as regards the practices used in Mathematics and Science classes.

Key words: *Teaching Practices in Mathematics and Science, Primary School.*

Teaching Practices

This study deals with the broad issue of teaching practices. Their importance lies in the fact that they define, to a large extent, the learning outcomes of teaching (Hora et al., 2013; Wieman & Gilbert, 2014). Despite their significance, quantitative research on them is not widely available and further studies are deemed as necessary (Mikeska et al., 2017). The topic of the study is to determine which teaching practices educators employ when teaching Mathematics and Science in the primary school settings. Teaching practices is an important dimension of the education process. It is these teaching practices that demonstrate how theories on effective teaching and learning are implemented in the actual classroom environment. They reflect and relate to strategies and actions that teachers use and implement in order to create the appropriate opportunities for learners to construct knowledge, by promoting the necessary conditions and motivation (Wieman & Gilbert,2014).

Teaching practices are highly determined by the teachers' general competencies and their professional background. Their knowledge on the subject and their personal skills and attitudes, affect their practices (Rowe, 2006; Svenja et al., 2012). They also depend on their wider beliefs and on social conditions that influence their work, such as the curriculum taught at schools, the actual goals of schooling and education, and the school culture and infrastructure. For example, teaching practices can show whether teachers consider learners as active participants during the learning process, or as simply passive receivers of knowledge. These are the main reasons why teaching practices have been drawing the attention of researchers during the last 20 years. By paying attention to these practices, it is possible to get an accurate impression on the overall cultural state and climate that exists in the educational system and context (Rowe, 2006; Svenja et al., 2012; Wieman & Gilbert, 2014).

A sufficient number of practices in different contexts, has been assessed regarding their advantages and disadvantages, (Rowe, 2006; Westwood, 2006). Precising the appropriate teaching practice and deciding which one is effective and which one is not, has been a topic of controversy.

Recent research has stressed the need for teachers to implement practices which are more oriented towards inquiry-based learning. The latter is defined as a 'student-centered, active, learning approach focusing on questioning, critical thinking, and problem solving (Barron and Hammond 2008, p.27). In particular, inquiry-based learning is an educational strategy whereby students follow methods and practices similar to those of professional scientists in order to construct knowledge (Keselman, 2003). It can also be defined as the process of discovering new causal relations, with the student formulating hypotheses and testing them by conducting activities or making observations (Pedaste et al., 2012). It can also be defined as the process of discovering new causal relations, where students formulate and test hypotheses, by engaging in challenging for them activities or by making observations (Pedaste et al., 2012). This, is achieved by encouraging learners to participate actively in identifying observations, forming research questions, hypothesizing, experimenting, drawing conclusions, researching data, applying new knowledge, and developing appropriate attitudes (Pedaste et al, 2015). Those practices seem to be beneficial for instruction, since they emphasize on learners' active involvement. The reason is that thanks to active involvement, learners might have the opportunity to work on real situations, which could also involve tasks such as experimentation, open-ended problems and problem solving (Chionidou- Moskofoglou 1999). Learners can understand effectively how knowledge constructing works. This creates a strong motivation to learn. In this case, learners might develop appropriate skills and attitudes towards learning on the taught subject. The teacher in this instance, has a guiding role in helping learners to participate effectively in the inquiry process, and in achieving the desired goals. This is probably why these approaches are in some cases named 'teacher -directed' (Rosenshire, 2012).

Rowe (2006) has pointed out that despite the fact that inquiry-based learning and the familiar teaching approach of constructivism have been supported by theory, teachers still seem to be avoiding the relevant practices in their work. Instead, there still seems to be a wide preference towards the so called 'traditional' practices, which are more teacher-centered, giving little room for learners' active participation during instruction.

Rosenshire (2012) has claimed that any efforts or studies aiming to identify the most appropriate practices that teachers need to use, require focusing on *three basic instructional topics* and research fields which may be independent, yet compatible in terms of practice suggestions. The *first* has to do with the way the *mind constructs* knowledge, perceives, analyses and applies information. *The second* is relevant to the *practices used by effective teachers*. *The third*, has to do with the ways by which *learners overcome challenging tasks.* These are perhaps the basic goals that practice design and implementation have.

In the same context, Hanie (2010) has pointed out *four themes* that research on effective teaching strategies should focus on. These themes reflect upon what is rational behind those practices. The *first theme* pertains *academic performance and expectations*. *The second t*heme refers to *effective management*- the use of different practices. The time spent on each practice is essential in that respect, as well. *The third* one has to do with the *role of learners* where active participation takes place. Lastly, *the fourth theme* is about *proactive planning*, which is closely linked to the identity of each session.

The scope of this research relates highly to the second theme. Thoughtful management of time and materials has been highly appreciated as a strategy by the participants during Hanie's research projects (2010). It has been necessary for teachers to reach the plenty and varying goals set either by them, or by external determinants (i.e. the curriculum taught). In these research projects, teachers frequently stated that they usually opted for different practices depending on the task, the unit, the subject, the level and the age of the learners. For that reason, it was important to plan and organize time carefully, and determine which teaching practice should be used, and when. This certainly implies that the teacher has developed a set of practices that can be used in a classroom setting whenever they are thought to be appropriate and necessary.

Within that scope, Creemers and Kyriakides (2006) have developed a list of practices that the teachers are advised to master. These are grouped into *eight different categories*, based

on the activities they relate to. The *first group* includes *practices* that *relate to the orientation of the instruction*. The *second* includes practices that focus on *how teaching should be structured*. The *third*, is about practices that have to do with *questioning*. The *fourth* includes practices about the *approach*, such as problem-solving and group work. The f*ifth* is about practices during the *application stage*. The *sixth* is about practices on the *learning environment* in the classroom. The *seventh* is about *time management practices*. Lastly, the *eighth is about assessment*.
Some of these practices might look very similar, depending on the role of the students and their participation in the teaching process. Also, they may serve as a transitioning tool that might transform passive pupils to active participants, something that most likely echoes the distinction between inquiry-based and teacher-centered learning.

Having all that in mind, Blazar (2015) planned and implemented a research to study the relationship between practices and effective teaching outcomes. Many factors, including the teachers' background and the learning contexts were studied. After thorough research into practices in science and mathematics sessions, it was suggested that it was not easy to precise which practices were appropriate in each case. That was due to the complicated nature of teaching and the complexity of goals to be achieved. The main suggestion drawn from that research was that it is beneficial to observe the practices that teachers implement in their classroom.

The Teaching Dimensions Observation Protocol (TDOP)

This research calls for a tool to observe the practices as they are used and implemented by primary teachers in actual classrooms. This tool should be appropriate to deal with two major interrelated challenges. The first is their direct identification, by pointing out issues and characteristics relevant to them (Blazar, 2015). Such issues would involve the level of the involvement of the learners in combination with the role they are given by their teachers during instruction. The second is to deal with the complexity of the teaching process and the variety of factors that are associated with.

The above challenges led to the development and introduction of the *Teaching Dimensions Observation Protocol* (TDOP). This is a descriptive protocol aiming to provide direct information about how instruction is done and provide such insights. Its structure is based on the finding that the teaching instruction is based on specific dimensions, directly observable. These can serve as parameters to show the actual characteristics of teaching. The focus of the protocol is on noting down the time of codes and traits. This can relate to calculation of the relevant time duration. There are *three basic directly observable dimensions* on teaching practices: The *first* has to do with teaching practices examining *whether the task observed is teacher or learner-centered*, as well as with what role each person involved undertakes. The *second* dimension has to do *with the nature of dialogue between learner and teachers*, with a focus on pointing out who has the basic role. The *third dimension refers to learning instruction* which helps pointing out what *means or artifacts, either conventional or technologically oriented,* the teacher uses to achieve the learning goals.

Apart from the above, there are *three optional dimensions* which can also give significant information. They include the *potential cognitive engagement of learners, their teaching style, (which relates to pedagogical strategies) and an optional dimension that has to do with the engagement of the learners*. All these basic or optional dimensions are useful in many cases of education research, which primarily investigates actual teaching implementation of theories, differences in teaching techniques in different subjects, contexts or groups, and the potential application of educational reforms (Hora et al, 2013; Hora, 2015).

This project emphasizes on teaching practices. The TDOP uses codes for practices. So, the observers, whenever they see a specific practice, they note the relevant code. Some practices and codes fit more into the teacher-centered model, where the teacher is the primary actor. These include (Table 1): *lecturing*, where the teacher is simple taking directly to the learners; *Lecturing with premade visuals*; *Lecturing with hand-made visuals lecturing with demonstration*, where the teacher uses equipment such as simulations to explain better what is described and *lecturing with questions*, where the teacher asks questions and the learners respond. There are other codes however, which fit more into a student-centered model, where the learner is the primary actor. These are: *group team work*, where the learners form groups to work out a task or question; *desk-work*, where each learner works individually; *classroom discourse*, where the instructor asks a question to stimulate discussion as students answer and ask questions between them; *multimedia*, which are used while the teacher does no interference, but relies on their use; *learners presentation*, where learners present work they have done to the class; and *play*. A combination of these practices can prove mastery on instruction, structuring, questioning, problem-solving, applying, managing classroom environment and assessing. All the above, are considered by Creemers and Kyriakides (2006) as crucial for teachers.

Table 1: The categories of teaching practices and their description.

Teaching Practices	Description
Lecturing	Instructor speaks to students with no media
Lecturing with premade visuals	Instructor speaks with premade visual media
Lecturing with hand-made visuals	Instructor speaks to students with hand-made visuals (e.g., writing on chalkboard)
Lecturing with demonstration	Instructor speaks while using demonstrations
Lecturing with questions	Instructor speaks while asking questions (two or more), the answers to which guide the discussion
Small group work	Students form into groups
Desk work	Students complete work alone at desk
Classroom discourse	Instructor asks a question and students answer and ask questions for themselves
Multimedia	Instructor plays a video/movie without speaking
Learners presentation	Learners present work they have done to the whole class
Play	Students perform roles

The project

The main use of the TDOP protocol is mostly for secondary and post compulsory education (Hora et al, 2013; Hora, 2015). There should be an interest therefore, in implementing it at a primary education level. Bearing in mind the above, this research study was designed to answer which teaching practices are more frequently used in elementary schools in Greece, with the help of TDOP. The focus was on the subjects of Science and Mathematics. The classrooms selected were the two final grades of Greek Elementary School, the 5th and the 6th. In fact, while mathematics is taught in all grades, science as an independent subject, is only taught in these two grades.

As it happens in almost every subject in Greece, there are teaching packages distributed by the ministry of education. These include three main books: the teachers' book (with detailed lesson plans), the pupils book (which is the main book used) and the workbook with contains exercises and tasks to be applied to new knowledge. The science subject has the following peculiarity: the workbook is in fact the book suggested to be used as the main textbook because it involves worksheets with simple experimental tasks, while the pupils' book is merely used for reading and reference (MINEDU, 2011).

The research questions

The identification of teaching process should start with initial recording and then continue with justification and analysis. This analysis is related to the structure of the TDOP and its capacity to contribute to education research and decision making, in general. Research questions should be formed in this context, and they must classify the practices recorded based on a theory-abided analysis. Therefore, the research questions should be compatible to points, or cases that the TDOP can analyze. Initially, it is important to simply point out which practices are favorite among teachers. A rather relevant and important point is to reach a conclusion as to whether the practices used tend to be closer to the teacher-oriented model, or to the learner-oriented model (Hora et al, 2013; Hora, 2015). Another point to make is to find out whether there is differentiation between the two subjects. In other words, it is important to see if the teachers implement different practices in mathematics and in science; the relevant literature suggests that there is a distinction depending on the subject taught (Blazar, 2015).

Bearing in mind the above, the questions of the research should be formed as follows:

1) What teaching practices are used by primary school teachers in science and mathematics?
2) Do teachers use a teacher-oriented, or a learner-oriented approach?
3) Is there differentiation in the teaching practices used in science and mathematics?

Research method

For the purpose of this research, 160 observations were carried out in each subject, 320 totally, in primary schools. More specifically, the sample was composed of 80 classes. In each class, two sessions of science and two sessions of mathematics were observed. Each session lasted 45 minutes. Following the instructions of the TDOP, each session *was broken up into intervals of five minutes*. The practice used during each interval was noted. Such practices included: lecturing, lecturing with pre-made visuals, lecturing with hand-made visuals, lecturing with demonstration, lecturing with questions, small group work, desk-work, classroom discourse, multimedia, learner's presentation and play. The data -which came from the above observation protocol- was then gathered and it was possible to calculate the amount of time each practice was used and estimate its frequency. The data was then gathered and analyzed further (Newhouse et al, 2007; Choy & Oo, 2012; Blazar, 2015).

This research is quantitative in nature. In order to have these research questions answered, it was important to know the average of every teaching practice. In fact, the average of practices used, should be calculated in each subject (science and mathematics). This can first show whether a practice is implemented or not, something that can provide answers to the first research question. In turn, the latter can give further grounds for analysis or comments and conclusions, such as which practice is the most frequently used. This might help the analysis of the second research question. As far as the third research question is concerned, the use of statistical distributions is required. In light of the scopes of this research, the most appropriate method seems to be the t-test, to compare numerical data from the different populations (Cohen et al, 2011; Swift & Piff, 2014).

Results and Discussion.

The means of frequencies of each teaching practice were calculated, separately for science and mathematics. These means were gathered and presented in Table 2. As far as the first research question is concerned, it is evident (table 2) that all practices are being implemented by the teachers of the sample, even with different frequencies. There is even an observed variety in the types of lecture used. In fact, according to Blazar (2015) this might imply that teachers are aware of the fact that different tasks might call for different practices, and that they are also aware of the varying roles that both them and the learners, need to undertake depending on the goals of each teaching task. More specifically, this shows that on the one hand teachers might consider that there are moments when it is up to them to take full control of the teaching process and have the learners simply listen. In that case, lecture is probably selected. On the other hand, there are moments where learners need to participate in the knowledge constructing process and they need to be given clear roles, while the teacher might need to work as a moderator. In those cases, practices such as discourse might be selected. This reveals an obvious variety in the strategies and approaches used by teachers in their instruction (Creemers & Kyriekides, 2006; Rowe, 2006; Svenja et al, 2012; Wieman & Gilbert, 2014). This is probably encouraging, as according to Haynie (2010), it could work as a stimulus for better learners' performance and academic achievement.

Table 2: percentage time over the total session time that each teaching practice was used in science and mathematics by the teachers of the study.

Teaching practices	Science	Mathematics
Lecturing	15,01	10,78
Lecturing with premade visuals Predesigned	11,83	3,78
Lecturing with hand-made visuals	3,97	2,93
Lecturing with demonstration	6,52	1,64
Lecturing with questions	26,47	16,05
Small group work	2,58	1,13
Desk work	8,97	7,15
Classroom discourse	17,12	9,25
Multimedia	3,81	0,65
Learners presentation	1,39	0,89
Pupils Play	0,13	0,27

As far as the second research question is concerned, *in both subjects*, there is *clear preference* on behalf of the teachers towards *teacher-centered practices*. More specifically, it seems that lecture with questioning is generally the most frequently used in both subjects. As it can be seen from Table 2, *lecture practices seem to be the dominant ones.* In fact, in the subject of science it is apparent that these lecture practices cover more than half of the duration of every session. Even though this is not the case in mathematics, lecture practices are frequently seen too, as it is shown in table 2. Among learner-centered practices, perhaps the only practice which seems to be comparatively frequent, is the one of discourse followed by the one of desk-work. Others, such as team work or presentation from learners, are rare. Play as a practice, is barely observed. So, even though the curricula and teaching packages are supposed to promote inquiry - based learning (MINEDU, 2011), teacher-centered practices are still favored (Rowe, 2006).

Despite this common tendency there are few points of differentiation between the two subjects. In the subject of science, the use of pre-designed materials seems to be more frequently used. This is likely to be due to the design of teaching package proposed by the national curriculum of the specific subject. It might be for that reason why practices such as classroom discourse, demonstration lecture and multimedia are much more frequent in science, than in mathematics (MINEDU, 2011). These findings are compatible to the research drawn conclusion, that the subject design influences the practices the teachers select (Svenja et al, 2012; Wieman & Gilbert, 2014).

Lastly, with regards to the third research question, when implementing the t-test the outcome shows that there is no significant difference in the scores for practices in science (M=8.9 SD=8.1) and in mathematics (M=5, SD=5.2) under the conditions used, with t=0.1914, p = 0.005

Despite the noticed differences in the data between the two subjects described within the previous research question, overall, there seems to be a common tendency in the trends towards the practices used in each subject. This tendency probably leans towards the teacher-centered practices. In other words, even if the teachers might fragmentally select different practices depending on what they have to teach each time, they may tend to opt for teacher-centered practices. (Svenja et al, 2012; Wieman & Gilbert, 2014).

Some Conclusion

The scope of this research was to provide insight on the teaching practices used in science and mathematics. Teaching practices are an important parameter of the educators' work, for they affect the learning outcomes (Svenja et al, 2012; Wieman & Gilbert, 2014). In literature, there have been numerous teaching practices described (Westwood, 2006). Some are more teacher-centered and others are more student-centered. The latter are expected to promote inquiry-based learning. In practice, it is still the former that seem to be more frequently used. Research in this topic, however, focuses mostly on secondary or higher education (Rowe, 2006).

This research investigated the practices used in science and mathematics, in Greek Primary schools. To accomplish the investigation, it was necessary to select an appropriate tool. Haynie, 2010 recommends to use a tool which gives direct information from observation. This tool, the TDOP, was selected for that purpose as it gives direct insight on teaching practices. These include: lecturing, lecturing with premade visuals, lecturing with hand-made visuals, lecturing with demonstration, lecturing with questions, small group work, desk-work, classroom discourse, multimedia, learner's presentation and play (Hora et al, 2013; Hora, 2015). After observing 320 fifth and sixth grade science and mathematics sessions, the teaching practices were recorded and analyzed (Cohen et al, 2011; Swift & Piff, 2014).

The findings showed that teachers use a variety of teaching practices. However, the most commonly used is the one of lecturing by the instructor. This practice is occasionally enriched with questions from the instructor to the learners, with the use of visuals. The dominant practices of teachers therefore seem to be of the teacher-centered paradigm (Rowe, 2006). In that case, teaching is approached as a "transfer" of knowledge from educators to learners. Educators have the role of the knowledge emitter, and learners have the role of the passive knowledge receiver.

With regards to the differentiation of teaching practices depending on the subject, even though there are various differentiations, overall, there are no significant differences in statistical terms.

Before generalizing these findings, it is necessary to point out the limitations of this research. The study focused on two grades of elementary school in a certain country. In the future, it might be helpful to triangulate with other data, as well as the pupils' and teachers' views (Cohen et al., 2011). Apart from this, this project focused solely on teaching practices. In order to have a complete picture of the learning environment it is necessary to research the teacher's interaction with the learner, the team work processes, the types of teaching materials that learners use, the learners' involvement and role in the activities carried out during instruction.

Teaching is a highly complex process. Therefore, our goal should be more and more contemporary, constructive teaching practices be included, through which the teacher might provide causative and challenging learning opportunities. These might encompass team work, play, dramatization and cross thematic curricular (meaningful-to-the-student) activities. It is imperative that those activities should take into account the learners 'personal learning style, as well as their socially and culturally shaped interests related to human values.

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Mediterranean Journal for Research in Mathematics Education
Vol. 16, 19-31, 2019

Gender Issues in Solving Problems in the Kangaroo Contest

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Abstract

The issue of attracting girls to mathematics has captured our attention when we were analyzing data from the final stage of the Kangaroo mathematics contest in Israel. With general finding showing boys having better results, further analysis of differences across Grades 2-6 indicates that in some grades the gap is smaller than in others. For instance, only insignificant differences were found in Grade 4 for all difficulty levels. Furthermore, on some tasks, across all five grades, the girls' performance was better than the boys'. In this respect, continuous investigation is needed to ascertain whether a certain trend exists and if so, what might be the possible factors that make it happen. Furthermore, qualitative data could be collected and analyzed about young students' thinking when solving different tasks to uncover other possible hidden factors.

Problem Statement and Context

Many educators express concern regarding the gender gap in mathematics performance and the underrepresentation of women in science, technology, engineering and mathematics (STEM) careers (Hyde et al., 2008). Gender inequity is particularly evident in data related to the number of girls that participated in the International Math Olympiad, or the number of female professors in university mathematics and engineering departments (Hyde & Mertz, 2009).

Several researchers pointed at mathematics performance in favor of boys (Aunola et al., 2004, Githua & Mwangi, 2003, Marsh et al., 2008), whereas others (Lindberg et al., 2010) claimed that no significant gender gap exists in mathematics. Moreover, Robinson and Lubenski (2011), and Brown and Kanyongo (2010) showed that over the last four decades, girls have achieved slightly better grades in mathematics than boys.

As Halpern et al. (2007) pointed out, "There are no single or simple answers to the complex question about sex difference in mathematics", and all "early experience, biological factors, educational policy, and cultural context" need to be considered when approaching this question. Gherasim et al. (2013) also argued that there is a need for more studies on gender differences in order to fill the gaps regarding the mechanisms that are conducive to enhancing mathematical performance.

In what way do gender differences appear (if at all) in the context of mathematics competition? Indeed, Niederle and Vesterlund (2010) found that gender difference in competitive performance does not reflect the differences in non-competitive performance. Gneezy et al. (2003) even revealed that gender gap in performance under competition conditions is three times greater than in non-competitive environments. Leedy et al. (2003) studied beliefs held by students participating in regional math competitions, as well as those held by their parents and teachers. They found that mathematics is still viewed as a male-dominated discipline, while girls and women fail to acknowledge the existence of the bias. They argue that the task of the school is not to ignore or deny differences in learning styles, attitudes and performance but to acknowledge and use them for developing strategies aimed at providing gender-equitable education. However, there is not enough data about how gender-related differences are manifested in mathematics competitions and what patterns emerge from these differences.

We started investigating gender issues in the context of the Virtual Mathematical Marathon by studying participation and performance (Applebaum et al., 2013). While observing students' participation during the first two years of the competition, we found that girls and boys showed similar patterns regarding the decision to remain in the competition, or to abandon it, regardless of the results in previous rounds.

In this paper, we analyze gender differences based on data from the 2016 Israeli competition, as part of an International Kangaroo Contest in which students from different countries solved the same problems, with the winners determined separately in each participating country. In the first stage, students took the test administered on the internet (students had to identify themselves) from home. Those who did particularly well in the first stage were invited to participate in the second stage, which took place about eight weeks later in a number of venues and was monitored by the contest organizers. In our paper, we use the data from the second stage. The performances are analyzed across the grades and the types of the tasks.

Gender Issue in Israeli National and International Tests

In National Israeli Math tests, for grade 5 gaps were found in favor of boys (about a quarter of standard deviation on average), and it seems to be expanding somewhat over the years 2012-2017.

At the same time in National Israeli Math tests, for grade 8, the achievements of boys and girls are similar throughout the years 2012-2017. The same picture is when comparing the achievements of Israeli boys and girls in TIMSS tests (2007,2011,2015).

The gap in favor to boys at an average of 16 points (about 1/6 of standard deviation on average) found again in the PISA tests in mathematics literacy in years 2006, 2009,2012. (Rapp, 2014)

Mathematical Competitions: Opportunities for Learning and Fun

Mathematical competitions in their current form boast more than 100 years of history and tradition, are organized in different formats, in different venues and for different types of students. They are considered to be "one of the main tools to foster Mathematical Creativity in the school system"(Silva, 2014). Kahane (1999) claimed that large popular competitions could reveal hidden aptitudes and talents and stimulate large numbers of children and young adults. Bicknell (2008) found the use of competitions in mathematics programs to have numerous advantages, such as student satisfaction, enhancement of students' self-directed learning skills, sense of autonomy, and cooperative team skills. Robertson (2007) reported that success in mathematics competitions, and mathematics achievements in general, seem to be linked to the love and interest instilled in students' learning experience. It also provides an opportunity to acquire high-level skills with extra training and the development of a particular culture that encourages hard work, learning, and achievement. The interplay between cognitive, metacognitive, affective, and social factors merits particular attention by researchers because it may give us more insight into the development of mathematical potential in young learners (Applebaum et al., 2013). Among the variety of competitions, the Kangaroo Contest stands out in its main objective: popularization of mathematics with the special purpose of showing young participants that mathematics can be interesting, beneficial and even fun (Kenderov et al., 2009).

Kangaroo Contest's target population is not just the most mathematically talented students. Instead, it aims to attract as many students as possible, with the purpose of showing them that mathematics can be interesting, beneficial and even fun. Although, sadly, it has generally become accepted that the vast majority of people find mathematics difficult, very abstract and unapproachable, the number of contestants in the Contest proves that this need not be the case. With a huge number of competitors, the Contest helps eradicate such prejudice towards mathematics.

Choosing appropriately challenging tasks is an important condition in the successful contribution of mathematical competitions to developing students' learning potential (Bicknell, 2008). In contrast to other more challenging competitions, the Kangaroo Contest' problems are more appropriate, according to the challenging task concept suggested by Leikin (2009). Such tasks should be neither too easy nor too difficult, so as to motivate students and develop their mathematical curiosity and interest in the subject.

Regarding the tasks and learning opportunities, Brinkmann (2009) mentioned that, when asked about the most beautiful mathematical problems, Grade 7 and 8 students named puzzles, while commenting that the problems should not be too difficult. For example, more than half of the students cited as 'a beautiful math problem' one of the 2003 Kangaroo Contest problems, which targeted spatial abilities in the context of paper folding (Brinkmann, 2009). Moreover, Applebaum's recent study confirmed earlier research that spatial thinking and mathematics are interrelated, especially in early grades, thus indicating that early intervention is crucial for closing achievement gaps in math (Applebaum, 2017).

Kangaroo Contest in Israel

Every student who wanted to participate in the contest (possibly sometimes due to the encouragement of the students' parents) could do it without any early condition (such as a test or an interview). The students only needed to pay a very low registration fee. The students came from different parts of Israel, from large cities as well as smaller cities and villages, and from different socio-economic backgrounds.

Kangaroo contest is part of an International Contest in which students from different countries cope with the same problems, but the winners are determined per country. Usually the contest has one test, both in Israel and in other countries. In 2016 the Israeli contest was unique, however, and involved two stages. In the first stage students coped with a test published in the internet (students needed to identify themselves) from their homes. Those who did particularly well on the first stage, were invited to participate in the second stage, which took place about eight weeks after the first stage in a number of sites and was monitored by the contest organizers.

The Study

Participants

The 345 participants (234 boys and 111 girls) aged 7-12 who took part in the final stage comprised 52 students in Grade 2, 70 in Grade 3, 87 in Grade 4, 76 in Grade 5, and 59 in Grade 6. It should be mentioned that in Israel, there was also an online stage, which we do not take into account in this paper. However, we noticed that in the first (online) stage, the ratio of boys to girls was approximately 3:2. We cannot definitively conclude that boys were more successful than girls in the first contest stage, because the first stage was not monitored, as students solved the tasks online from their homes.

Tasks

The test lasted 75 minutes. Students in 2nd grade had one version of the test; 3rd and 4th grade students had another version; and 5th and 6th grade students had a third version. Using any accessories other than pens and paper was forbidden. The test consisted of 24 problems for 2nd-4th graders and 30 problems for 5th-6th graders. Almost all the tasks in the Kangaroo Contest differed, in both style and type, from the tasks students usually encounter in their classroom textbooks. All tasks were multiple-choice and were ordered according to increasing difficulty (Easy – Average – High). The problems of the international contest are selected each year from a long list of problems provided by the team leaders from all the participating countries.

For each problem, a choice of five possible answers was provided. Problems 1-8 (1-10 for grades 5-6) give 3 points for a correct answer and deduct 0.75 points for an incorrect answer. Problems 9-16 (11-20 for grades 5-6) give 4 points for a correct answer and deduct one point for an incorrect answer. Problems 17-24 (21-30 for grades 5-6) give 5 points for a correct answer and deduct 1.25 points for an incorrect answer. The point reduction for incorrect answers ensures that a completely random guess (with a probability of 20% to be correct and 80% to be incorrect) has an expectation of zero points. Not providing an answer at all gives zero points across all difficulty levels.

Research Questions

In this study, we use data from the competition's second stage to investigate the following research questions: (1) Does girls' performance differ from that of boys? If so, how does it differ across the grade levels? (2) What are the gender-related patterns across the different types of tasks? and (3) Does age influence on boys' and girls' performance in the same way?

The results

Regarding the first research question, in Table 1 we present the descriptive data according to boys' and girls' performance in the final (monitored) stage of the 2016 Kangaroo Contest. According to the data presented below, in all grades and in all levels of difficulty, boys seem to exhibit greater success in solving problems.

In Grade 2 we found that the differences between boys and girls performances increase according to level of difficulty. In the other grades, the dynamic regarding the difficulty level was quite variable. The biggest gap per difficulty level between boys' and girls' scores ($\bar{x}_{boys} - \bar{x}_{girls}$) was found in 2nd grade; then it decreases across Grade 3; is the smallest in Grade 4; and then the gap increases again in Grade 5 and decreases slightly in Grade 6.

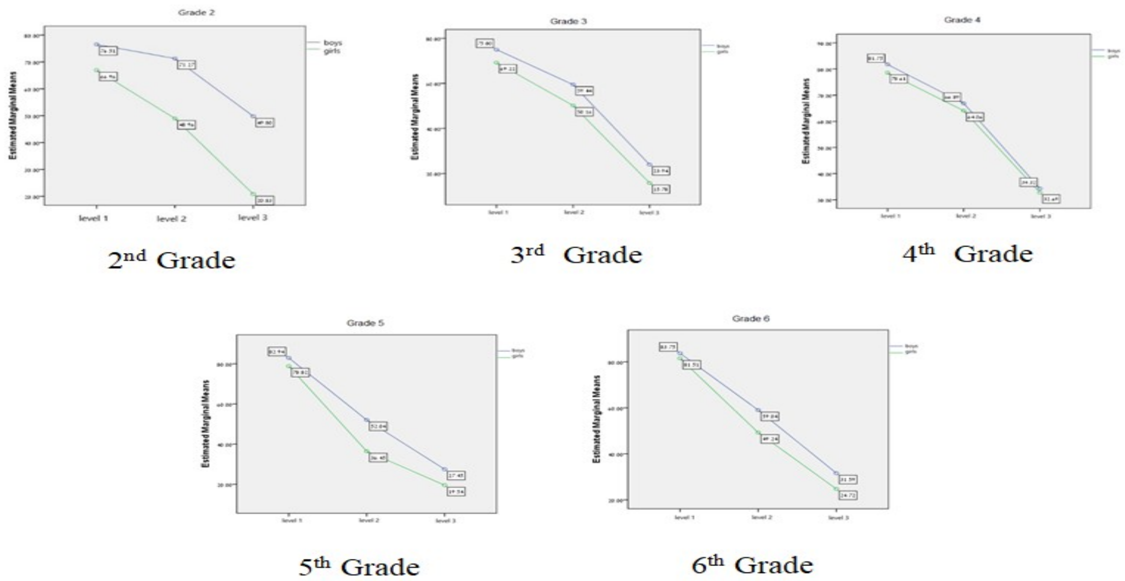
Table 1. General data of boys' and girls' performance in Kangaroo 2016

		Whole test	Easy level	Average level	High level
Grade	Gender	Mean, (St. Dev)	Mean, (St. Dev)	Mean, (St. Dev)	Mean, (St. Dev)
2	Boys (N=31)	63.63(18.28)**	76.51(18.09)*	71.27(21.79)**	49.80(25.64)**
	Girls (N=21)	41.74(21.35)	66.96(14.37)	48.96(27.45)	20.83(30.66)
3	Boys (N=50)	48.52(22.11)	75.00(21.96)	59.44(23.75)	23.94(31.09)
	Girls (N=20)	40.60(19.15)	69.22(21.30)	50.16(27.57)	15.78(22.18)
4	Boys(N=62)	57.04(17.27)	81.75(15.95)	66.88(18.90)	34.32(27.51)
	Girls (N=26)	54.63(21.41)	78.61(25.26)	64.06(17.48)	32.69(33.12)
5	Boys (N=49)	65.80(20.84)*	82.94(13.45)	52.04(20.32)**	27.45(21.80)
	Girls (N=27)	53.15(19.71)	78.82(12.86)	36.45(24.45)	19.53(17.03)
6	Boys (N=41)	71.52(23.69)	83.75(12.99)	59.04(26.05)	31.59(22.85)
	Girls (N=18)	62.62(25.19)	81.51(13.31)	49.24(27.97)	24.72(24.34)

** $p<0.005$, * $p<0.05$

In Figure 1 we present five diagrams that illustrate the dynamics of boys and girls performance according to level of difficulty.

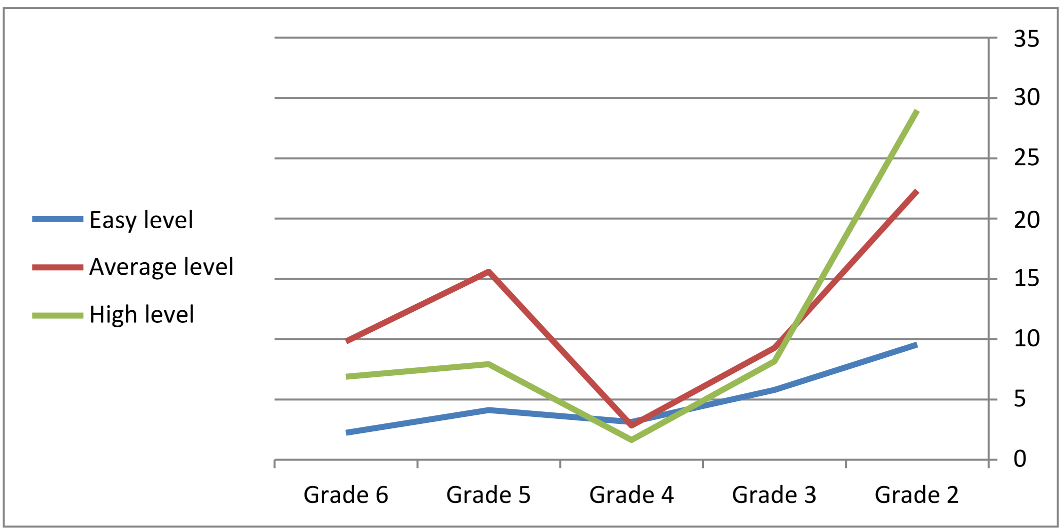
Figure 1: Boys and Girls Performance at different difficulty levels



At Grade 2 we found that the difference increases according to difficulty's level. In other grades mixed changing of differences was found. In general no some common pattern of difference changing between boys and girls scores was found for different grades.

The data presented on Fig 2 let us to gain that there was some pattern of gaps' changing across grades 2-6: the biggest gap per difficulty level between boys and girls scores ($\bar{x}_{boys} - \bar{x}_{girls}$) discovered in 2nd Grade; then it decreases across Grade 3, gets smallest results at Grade 4 and then increases again in Grade 5 and decreases a little in Grade 6.

Fig 2. Boys and girls differences ($\bar{x}_{boys} - \bar{x}_{girls}$) according to grade and difficulty level



Furthermore, an independent sample t-test was performed showing that only 2nd - and 5th - grade boys' and girls' scores displayed significant differences. The differences between boys’ and girls’ performance in 3rd, 4th, and 6th grades were not significant.
With regard to question 2, we decided to focus on Grades 2 and 5, where gender-related differences were significant. For Grade 2, the problem that resulted in the largest gap between scores of boys and girls was problem #19 in the contest:

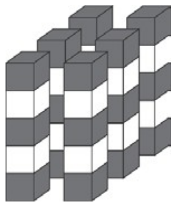
#19. At the magic shop, you cannot buy anything, but you exchange items for other items. A flying carpet can be exchanged for two magic hats; for each magic hat, you can get 3 magic sticks. How many magic sticks can you get for 2 flying carpets?

(A) 20 ✓ (B) 12 (C) 8 (D) 6 (E) 4

For this problem, the boys' mean was more than 6 times greater than that of the girls:
$\bar{x}_{boys}(2^{nd}\quad grade) = 2.217,\quad s = 3.6124$, $\bar{x}_{girls}(2^{nd}\quad grade) = 0.357,\quad s = 2.685$,
$t = 2.29,\quad p < 0.05$.

There were 3 tasks (out of 24) where girls were more successful than boys, but in all cases the differences were not significant. One of these tasks (#12 - Average Level,
$\bar{x}_{boys}(2^{nd}\quad grade) = 3.39,\quad s = 1.626$, $\bar{x}_{girls}(2^{nd}\quad grade) = 3.52,\quad s = 1.504$,
$t = -.30,\quad p = 0.75$) is presented below:

#12. Six towers were built with grey cubes and white cubes. Each tower was made with five cubes. Cubes of the same colors do not touch. How many white cubes are there?



(A) 10 (B) 11 ✓ (C) 12 (D) 18 (E) 30

For the 5th grade, the problem with the largest gap between boys' and girls' scores was problem #17 in the contest:

17. The area of a rectangle equals 12 cm^2. If the lengths of the rectangle are natural numbers, what can be the perimeter of the rectangle?

(A) 20 cm ✓ (B) 26 cm (C) 28 cm (D) 32 cm (E) 48 cm

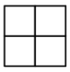
We found that in task #17 (Average Level) the mean of boys' scores was more than 75% higher than the mean of girls' scores: $\bar{x}_{boys}(5^{th}\quad grade) = 3.0408,\quad s = 1.9252$,

$\bar{x}_{girls}(5^{th}\quad grade) = 1.7037,\quad s = 2.4466$, t=2.45, p < 0.05

We found that only in task #23 (High Level) was the girls' performance significantly better than that of the boys: $\bar{x}_{boys}(5^{th}\ \ grade) = 0.3316,\ \ s = 2.5741$,
$\bar{x}_{girls}(5^{th}\ \ grade) = 1.8981,\ \ s = 3.0691, t = 2.251,\ \ p < 0.05$.

23. A large cube was built from 8 small cubes, some black and some white. Here are 5 faces from the big cube:

What does the cube's sixth face look like?

(A)  (B)  (C)  ✓ (D)  (E) 

In 5^{th} grade there were in total 7 tasks out of 30 in which girls were more successful than boys. In Grades 3, 4 and 6, where differences for research question 1 were not significant, there were more tasks in which girls outperformed boys: in 3^{rd} grade - in 7 out of 24 tasks; in 4^{th} grade - 9 out of 24 tasks and in 6^{th} grade - 8 tasks out of 30. All of these differences, however, were not significant.
With regard to question (3) we compared separately boys' and girls' scores differences according to grades 3 and 4 and then to grades 5 and 6. (We should remind that 3^{rd} and 4^{th} grades' students had the same test and 5^{th} and 6^{th} grades' students also had the same test.) We found positive correlation (in boys and girls) between students' age and their success in the test (Table 2 and 3).

Table 2. Comparing boys' scores in 3^{rd} and 4^{th} grades

Level of difficulty	Easy	Average	High	Total
Boys (N=50), Grade 3	75	59.44	23.94	48.52
Boys (N=62), Grade 4	81.75	66.88	34.32	57.04

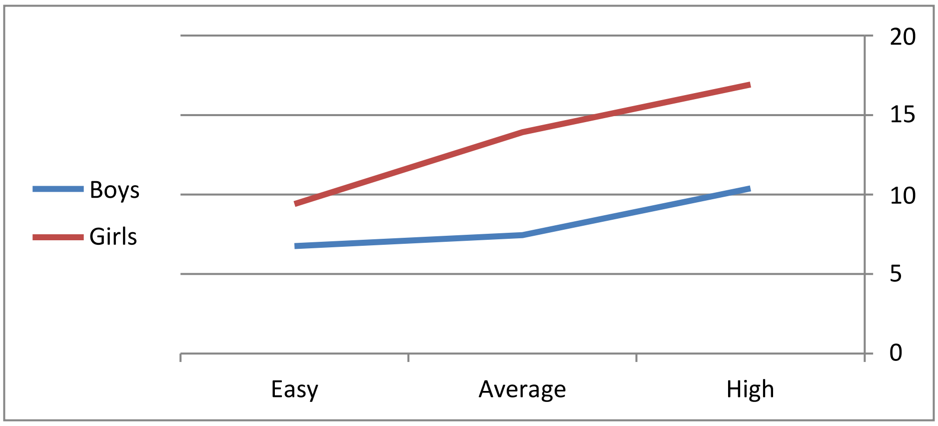
We compared improving scores of boys and girls separately moving from Grade 3 to Grade 4 and received the data presented in Table 4:

Table 4. Improving scores from Grade 3 to Grade 4

Level of difficulty	Easy	Average	High
$\bar{x}_{boys}(Grade\ \ 4, N = 60) - \bar{x}_{boys}(Grade\ \ 3, N = 52)$	6.75	7.44	10.38
$\bar{x}_{girls}(Grade\ \ 4, N = 26) - \bar{x}_{girls}(Grade\ \ 3, N = 20)$	9.39	13.9	16.91

We found that age played the positive factor stronger in girls' performance, and they improved their scores better than boys (Fig 3).

Fig 3. Comparing differences in boys and girls, in 3rd and 4th grades' scores



In Tables 5 and 6 we present the data compares the 5th and 6th grade students' scores divided to gender and level of difficulty.

Table 5. Comparing boys' scores of 5th and 6th grades

	Easy	Average	High	Total
Boys (N=49), Grade 5	82.94	52.04	27.45	65.80
Boys (N=41), Grade 6	83.75	59.04	31.59	71.52

We revealed that 6th grade boys were more successful than 5th grade boys but the differences were not significant (look at Table 6).

Table 6. Comparing 5th and 6th grades girls' scores

	Easy	Average	High	Total
Girls (N=27), Grade 5	78.82	36.45	19.54	53.15
Girls (N=18), Grade 6	81.51	49.24	24.72	62.62

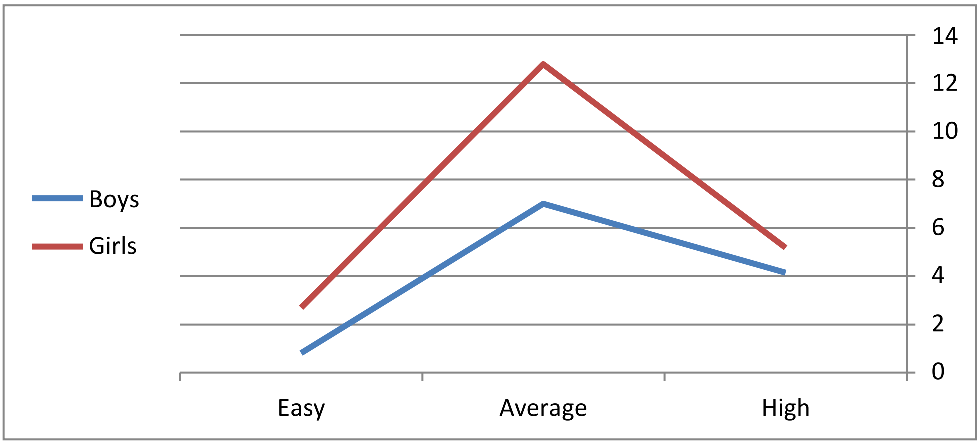
We revealed that 6th grade girls were more successful than 5th grade girls but the differences also were not significant.
The results of comparing boys and girls improved scores from Grade 5 to Grade 6 presented in the Table 7.

Table 7. Improving scores from Grade 5 to Grade 6

	Easy	Average	High
$\bar{x}_{boys}(Grade\ 6, N=49) - \bar{x}_{boys}(Grade\ 5, N=41)$	0.81	7	4.14
$\bar{x}_{girls}(Grade\ 6, N=27) - \bar{x}_{girls}(Grade\ 5, N=18)$	2.69	12.79	5.18

Like in grades 3 – 4 we found that age played the positive factor stronger in girls' performance than in boys' performance (see Fig 4).

Fig 4. Comparing differences in boys and girls, in 5th and 6th grades' scores



Discussion and Conclusions

The gender issue in mathematics, i.e., girls being underrepresented in the STEM-related fields, still remains unresolved. This is why every inclusive endeavor to popularize mathematics by attracting all students merits particular attention. Kangaroo contests are exemplary of such inclusive competitions. With limited research available on the patterns of participation and the results of the contest, it is important to investigate gender-related issues. While analyzing the results of participants from Grades 2-6 in the 2016 Israeli Kangaroo contest, according to gender, we found, unsurprisingly, that boys generally performed better than their female counterparts.
Despite the fact that the differences were found in all grades, only for Grades 2 and 5 were they statistically significant. Boys showed better results than girls in other grades, as well, although the differences were not significant, especially for Grade 4. Another finding that requires further investigation was that some tasks were more successfully solved by girls, among them those that target spatial abilities.

The data do not yield any far-reaching conclusions about the factors that might explain these findings.

Some other aspects like parents' encouragement to participate and gender issues in using technology should be taken into an account.

Yet, it is worthwhile to conduct further research and analysis over the next few years to see if the pattern re-appears. Furthermore, deeper analysis is needed regarding the tasks that were solved better by girls and the methods they used in solving them.

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Mediterranean Journal for
Research in Mathematics Education
Vol. 16, 33-52, 2019

Inclusion of Financial Literacy Goals in Secondary School Curricula: Role of Financial Mathematics

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Acknowledgement
The authors would like to thank Wim Van Dooren for his research assistance.

Abstract

The best policy option to implement financial education at school is still open for debate. We add to this discussion by examining the possible contribution of financial mathematics in the curriculum of secondary schools. Results of an exploratory study based on a pre- posttest design show that financial mathematics positively affects students' general financial literacy levels in the short run by raising their understanding of (math-related) financial literacy concepts and the application of financial math methods to the financial world. The effect is stronger for female students suggesting that financial mathematics can help reducing the gender-related financial literacy gap. Spillover effects to other financial literacy topics not covered in financial math curriculum are not present. Overall, financial mathematics appears to be a valuable course in an integrated cross-curricular approach to financial education.

Key words: *Consumer education, Curriculum design, Educational finance, Financial literacy, Mathematics of finance.*

Introduction

Financial illiteracy is widespread and has important economic consequences, so the need to increase the level of people's financial literacy is generally recognised (Lusardi & Mitchell, 2014). Research especially demonstrated the low level of financial literacy of different social sub-groups, such as youth, women, lower-income people and weakly-integrated immigrants (Chen & Volpe, 2002; De Bassa Scheresberg, 2013; Erner, Goedde-Menke, & Oberste, 2016; Lusardi, Mitchell, & Curto, 2010; Mandell, 2008a; Xu & Zia, 2012). Initiatives that may empower these vulnerable groups receive ample attention in recent research and developmental actions on financial literacy (Blue, O'Brien, & Makar, 2018; Sawatzki, 2017). In its efforts to specifically combat financial illiteracy of young people, the Organisation for Economic Co-operation and Development (OECD) recommends that financial education starts at school to ensure exposure at an early age (OECD, 2005).

There is a broad consensus to start improving financial literacy early because sound financial behaviour developed at a young age acts as a catalyst for sensible financial behaviour later in life (Beverly & Burkhalter, 2005; Martin & Oliva, 2001). Adolescents are already confronted with various financial options at a young age (saving and spending, bank accounts, online shopping, cell phone plans …). Over their lifetime they are also likely to be confronted with more complex and riskier financial products than their parents (Lusardi et al., 2010; OECD, 2014a).

It is thus not surprising that financial literacy programs for schools take a prominent place in youth financial literacy policies worldwide. Delivering financial education at school has a number of distinct benefits (see, amongst others, Messy, 2011; OECD, 2014a; Van Campenhout, 2015). Firstly, it indeed ensures that financial literacy is introduced at an early age and that aspects of financial literacy can be introduced gradually over the curriculum. In addition, childhood represents many teachable moments with potential stronger impacts on desirable financial behaviours and the development of sound financial attitudes[(i)]. Secondly, it ensures that all children will be reached. Without school-based financial literacy initiatives we run the risk that financial illiteracy carries over from one generation to the next, thereby reproducing or even amplifying inequalities over time (Messy, 2011). Indeed, previous research has documented that financial literacy levels tend to be positively correlated with socio-economic status, but also that children from less wealthy families may receive less financial education at home (De Bassa Scheresberg, 2013; OECD, 2013, 2014b; Shim, Barber, Card, Xiao, & Serido, 2009).

In view of the arguments raised above, including financial education in the official school curriculum is considered one of the most efficient policy options to deliver broad-scale financial literacy initiatives (OECD, 2014a). Such initiatives can be mandatory or on a voluntary basis. There is however no consensus on how this policy can best be implemented in the existing educational structures. Indeed, the optimal manner in which financial literacy goals can be integrated in curricula and the best way to expose children to financial literacy at school are still open for debate. Financial literacy could be given as a stand-alone course, as an explicit module in one or more courses, or integrated in relevant courses such as mathematics, economics, citizenship, etc. (OECD, 2012b). Although a stand-alone course has the advantage that students would get sufficient exposure to financial literacy subjects, it is often difficult to implement in view of overloaded curricula and lack of resources and time (OECD, 2014a). In this respect, it is not surprising that the majority of countries that include financial education in the curriculum have done so by integrating it into several courses through a cross-curricular approach (OECD, 2012a). Mathematics is the most popular course that is considered to implement financial education goals, probably due to the established positive association and theoretical connectedness between financial literacy and mathematical skills (Lusardi et al., 2010; OECD, 2014a).

Financial literacy and mathematics

The positive relation between mathematical competence and financial literacy is widely recognized in the literature. Mathematical ability is often an implicit or explicit part of definitions of mathematical literacy (see, e.g., Worthington, 2006) and of instruments to measure financial literacy (see, e.g., Lusardi & Mitchel, 2011; OECD, 2014c).

Cole, Paulson, and Shastry (2014, 2016) were able to establish a causal relation between increased US state math requirements and superior financial outcomes, including greater market participation, higher investment income, better credit management and lower probability of being delinquent on a loan. They further showed that this result was driven by improvements in investment performance, rather than by increased labour income. Similar results were found by De Bassa Scheresberg (2013) who showed that young adults who displayed higher confidence in their mathematical knowledge demonstrated better financial behavior. More specifically, they were less likely to engage in high cost borrowing behavior and were more likely to have precautionary savings or retirement savings.

Detailed accounts of the relationship between adolescents' financial literacy and mathematics in several regions around the world were provided by the 2012 and 2015 Programmes for International Student Assessment (PISA) on financial literacy, conducted in, respectively, 18 and 15 countries (or economies) with a total of about 29 000 and 53 000 15-year-old students participating (OECD, 2014c, 2017). An important conclusion is that financial literacy and mathematical literacy are highly correlated (on average across the participating OECD countries and economies, r = 0.83 in PISA 2012 and r = 0.74 in PISA 2015), although they do not coincide completely. Another way of looking at this relationship is the percentage of the total variation in financial literacy scores that can be explained by mathematics. On average about 12% of this variation across OECD countries and economies can be attributed to mathematics in PISA 2012, compared to 6% in PISA 2015. Comparing financial literacy scores of students with comparable math skills, there is a wide dispersion in the documented financial literacy proficiency. PISA 2012 revealed that in some well-performing countries such as the Czech Republic and Australia, levels of financial literacy proficiency are more than 15% higher than what could be expected based on mathematical proficiency levels, while in other, weak-performing countries such as France, levels of financial literacy proficiency are about 25% lower than those of students with comparable math proficiency. For the Flemish Community of Belgium, the region in which the study reported in this paper was conducted, financial literacy scores are significantly above OECD average and about 9% higher compared with matched participants, while the overall correlation between math and financial literacy (r = 0.86) is just above average. Also in PISA 2015, the actual financial literacy scores are different from the ones expected on the basis of math performance across countries. For a detailed overview, we refer to the official PISA report (OECD, 2017), but in the Flemish Community of Belgium, financial literacy scores are again significantly above OECD average and about 14% higher than those of participants matched on math proficiency, while the overall correlation between math and financial literacy is above average (r = 0.80). In sum, the reported PISA results suggest that although financial literacy is not solely determined by mathematical competence, mathematical skills taught at school will help students to attain higher levels of financial literacy.

The course in which the financial literacy-mathematics association can be maximally exploited is financial mathematics. Financial mathematics is a compulsory or optional part of the secondary mathematics curriculum in several countries. We empirically examine the possible contribution of financial mathematics to help raise students' financial literacy levels.

Therefore, we compare financial literacy scores of students before and after they have attended a financial mathematics course. By doing so, we can gain insight in the students' progress in financial literacy levels. Our experimental approach, based on a pre- posttest design, is different from previous, mostly correlational research that concentrated on the possible cross-sectional association between financial literacy and mathematics at an aggregate level (cf. supra).

As mentioned, our study was conducted in the Flemish Community of Belgium. This community provides an interesting case for two reasons. Firstly, in 2016 the Flemish Minister of Education announced the introduction of financial literacy as one of the four basic competences (besides Dutch, mathematics and digital competences) for the secondary curriculum (Crevits, 2016), but the actual design regarding the implementation is still unsettled. Hence, research to support this decision is more than welcome. Secondly, the Flemish financial math curriculum goes beyond a straightforward review of math-technical aspects and explicitly focuses on the application of math concepts to the financial world (Deprez, Eggermont, & Roels, 1996). Note that this approach is closely related to the one in England. The national mathematics curriculum (stage 4) indicates that:
'They [students] should also apply their mathematical knowledge wherever relevant in other subjects and in financial contexts.' (Department of Education, 2014, p. 3)

In line with (Davies, 2015, p. 311) who argues that financial decisions do not take place in a vacuum but arise from a system that determines the context in which individuals, financial services and government interact, the financial math curriculum in the Flemish Community also stresses the link with the economic and legal climate:
'The theoretical knowledge cannot be viewed separately from reality. As future consumers, pupils need to become proficient in an assessment of the ample supply of products and services in the financial world. (…) Financial mathematics is strongly interrelated with the prevalent economic climate and legislation. As a result, teachers should keep abreast with the evolution of interest rates, withholding tax rules and other relevant regulations, etc.' (VVKSO, 2004, pp. 54–55).

This holistic approach to mathematics and its applications is also reflected in the secondary mathematics curriculum in England. Indeed, the secondary national curriculum highlights the importance of mathematics to both everyday life, alpha sciences and its applications (science, technology and engineering), as well as its necessity for financial literacy and most forms of employment (Department of Education, 2014, p. 3).

Overall, the current practice in the Flemish Community is commensurate with the call in the financial literacy education literature to move towards initiatives that would stimulate effective financial behaviour (i.e. result in successful application of the acquired financial knowledge and skills), and away from initiatives that only aim at increasing financial knowledge. The latter has been criticized for assuming an automatic causation running from improvements in financial knowledge to positive changes in desired financial behaviour (see among others García, 2013; Van Campenhout, 2015). This study will also indirectly show whether in terms of curriculum development such an application-driven learning approach hold promise to achieve financial education objectives. In view of the parallels between the Flemish approach to mathematics and the one put forward in other countries like the UK, our results based on Flemish students could also be insightful for the implementation of financial literacy programmes in other countries.

Because financial mathematics is not part of all Flemish secondary schools curricula(ii), results of this study also stimulate the discussion regarding the inclusion of financial mathematics in the curriculum, both in Flanders and internationally. On a broader scale, this study provides further insights on the implementation of financial literacy objectives through a cross-curricular approach.

Material and methods

Eighty-four 16–18-year-old secondary school students in the Flemish Community of Belgium, for whom financial mathematics is part of their math curriculum(iii), participated in the study. The sample group was subjected twice to a financial proficiency test: A pretest – taken just before the start of the financial mathematics course – and a posttest just after they have taken the financial mathematics course. Post- and pretest were equivalent, which was established by a panel of experts.

The written tests consisted of 21 multiple-choice questions regarding financial literacy. Questions covered a variety of basic financial topics and were chosen from existing tests designed to measure financial literacy among adolescents (Lusardi & Mitchel, 2011; OECD, 2014c) or were specifically constructed for this experimental research action. Each question had four alternative answers. For further analysis, questions were categorized into the following three categories: (1) financial mathematics methods; (2) financial mathematics concepts; and (3) spillover effects. Categories were not disclosed to participants and the questions were randomized over categories and tests. For the sake of brevity, we refer to the three categories as 'Methods', 'Concepts', and 'Spillovers' in the remainder of the article. The first two categories of financial literacy questions refer to the learning content of the financial math curriculum. 'Methods' consists of financial literacy questions in which students have to apply mathematical methods that have been reviewed during the financial math lessons. Typical questions are about the application of simple and compound interest rate calculations, discount calculations, and applications related to annuities and loans. The second category 'Concepts' refers to questions that test aspects that belong to the context of the financial math lessons, but the answer does not require the students to perform any kind of calculation. Examples include questions on the concepts of checking and savings accounts, loans and purchases by deferred payments, etc. The final category 'Spillovers' consists of questions that test issues that are not part of the learning outcomes of financial mathematics, but are part of financial literacy. Examples of topics include questions related to diversification, insurance, stock market, safety of financial transactions, etc. Worded differently, these questions test whether financial math competencies also generate spillover effects to other domains of financial literacy that are not explicitly reviewed in the financial math course. The test also included a number of general questions related to the participant's personal background or social status, allowing us to control for personal and social correlates documented in the previous literature. Besides age, gender, local speech used in a family setting, also results on math and language proficiency and experience with money were surveyed. The financial literacy questions of the test are added in an Appendix.

Hypotheses

Our main focus is to examine whether financial mathematics could help promote financial literacy at school. Previous research has documented a positive relationship between mathematical proficiency and financial literacy. In addition, OECD advocates exposing young people to financial education in a scholarly environment. So we first hypothesize that financial mathematics positively affects students' financial literacy. In particular, we predict that this progress will manifest itself with respect to skills and knowledge covered by the financial algebra curriculum. Consequently, we expect that students who attend a financial math course will improve their financial literacy scores, both in general, and in particular on the categories ‘Methods’ and ‘Concepts’ as identified in the section Material and methods.

In addition, it is important to gain a more detailed insight into which financial literacy aspects are addressed effectively (or not) in order to develop a cross-curricular approach to financial literacy. Indeed, it is unlikely to assume that current financial math courses provide an all-in-one solution to financial education. We investigate the differential effect of financial mathematics for the three categories of financial literacy questions (‘Methods’, ‘Concepts’, and ‘Spillovers’) as identified in the section Material and methods. It is likely that students’ progress with regard to financial literacy aspects that are covered in financial mathematics is more explicit. Hence, we hypothesize that the progress in financial literacy after the completion of the financial math course is higher for topics covered by the financial mathematics curriculum compared with topics not targeted in this curriculum. In line we predicted a higher increase in students’ financial literacy scores from pre- to posttest for the categories ‘Methods’ and ‘Concepts’ than for the category ‘Spillovers’.

Finally, we examine the possibility of a gender effect. It is difficult to postulate an expected relationship a priori. On the one hand, the 2009 PISA study found that in the majority of countries (including Belgium), boys outperform girls in mathematical skills (OECD, 2011). In addition, males have higher financial literacy levels than females. On the other hand, based on a study of 34 schools in the Flemish Community, Van Houtte (2004) found corroborative evidence that boys underperform girls in terms of academic achievement. With respect to general schools – which are also the subject of this study – they conclude that the difference is attributable to boys’ study culture (showing less student involvement and learning motivation than girls’ culture). While the former might support the hypothesis that boys might benefit more than girls from financial mathematics, the latter is supportive for an opposite effect: the academic outperformance of girls compared with boys might result in a more distinct positive change in financial literacy. Given that the sign of the gender effect is an empirical issue, we formulate the general hypothesis that the effect of financial mathematics on students’ financial literacy is different for female students (compared with male students).

Results

We apply a pre-posttest design in which subjects take a written financial literacy proficiency test before and after they have taken a financial math course in order to examine the (short term) effects of financial maths on various aspects of financial literacy. Results are reported for seventy students that took both the pre- and posttest.

Table 1. Mean and standard deviation of students' financial literacy scores in general and on each of the three test categories for the pre- and posttest

	Pretest	**Posttest**	**Difference pre-posttest**
	Mean (SD)	Mean (SD)	
Financial literacy	12.43 (2.806)	14.47 (2.614)	2.04***
Methods	4.24 (1.245)	5.14 (1.243)	0.90***
Concepts	3.11 (1.460)	4.21 (1.261)	1.10***
Spillovers	5.07 (1.171)	5.11 (1.149)	0.04

Note: N = 70; *** indicates statistical significance at the 1%-level.

We first examine the effect of financial mathematics on the average level of financial literacy, as well as its effect on financial literacy aspects related to the methods and concepts of financial maths. Results are summarized in Table 1. Differences between the mean scores in the pre- and posttest are evaluated based on a paired sample T-test. The results provide a strong confirmation of our hypothesis concerning students' progress on financial literacy: With the exception of the category 'Spillovers', the average score on the posttest is significantly higher than on the pretest (p-value of a paired sample T-test is lower than 0.001 in each instance). These results support our expectation that financial mathematics can help promote financial literacy in general, and financial literacy skills and knowledge in particular.

In additional analyses, we investigate whether the documented positive effect is different for the three subcategories. The respective hypothesis is confirmed too. Based on an ANOVA analysis and accompanying Tukey HSD-tests we find that there is a significant difference between the effect on the two financial mathematics categories ('Methods' and 'Concepts') compared with the category 'Spillovers'[iv]. Comparing the category 'Methods' with the category 'Concepts', we do not find a significant difference, indicating that the holistic approach of financial math teachers in which they do not only focus on the math- technical aspects results in a broader impact on students' financial literacy.

To investigate a possible gender effect, we analyse the effect of financial math separately for male and female students. Results reported in Table 2 indicate that the effect of financial maths is not identical for male and female students. The difference in pre- and posttest scores is 2.78 for female students and only 1.26 for male students. The gender effect is also significant at conventional levels of significance (p-value equals 0.019).

Hence, female financial literacy levels increase more compared with male financial literacy levels. Subsequent ANOVA analyses reveal that the gender effect is attributable to a stronger significant increase for females on 'Concepts' which might be indicative for the fact that girls superior study culture pays dividends. This result is encouraging in view of the generally documented lower average financial literacy level of women. It indicates that including a financial math course in the curriculum can help to level off gender-related differences in financial literacy.

Table 2. Mean and standard deviation of the pre-posttest difference scores of female and male in general and on each of the three test categories

Pre-posttest differences	**Female (*N* = 36)**	**Male (*N* = 34)**	**Gender differences**
	Mean (SD)	Mean (SD)	
Financial literacy	2.78 (2.642)	1.26 (2.664)	1.52**
Methods	0.78 (1.533)	1.09 (1.564)	-0.31
Concepts	1.61 (1.517)	0.65 (1.773)	0.96**
Spillovers	0.39 (1.128)	-0.15 (1.760)	0.54

Note: ** indicates statistical significance at the 5%-level.

The effect of financial mathematics on financial literacy may be related to general math and language skills. In addition, the possible benefit from following a financial math course may be conditional upon the level of financial socialization received at home. Overall, we observe that these variables are unrelated to the documented increase in financial literacy. Regarding financial socialization, we find no significant differences between changes in financial literacy in the pre- and posttest for students that score high or low on financial socialization based on a Kruskal-Wallis test (*p*-value, 0.751). Similar conclusions are reached when we investigate the relation between financial socialization and 'Methods', 'Concepts', and 'Spillovers'. Turning to math and language skills, no evidence is found for a significant positive correlation between these skills and the documented overall effect on financial literacy or any of the subcategories[v].

In short, the progress in financial literacy associated with the completion of a financial math course is not conditional upon previous levels of financial socialization or math and language skills. Hence, results seem to indicate that financial mathematics can help promoting financial literacy for all students, not only the gifted or weak ones. As such, this strengthens the case for including financial mathematics in the curriculum as a means of promoting financial literacy given that the course is relevant for all students.

To move beyond the average effect of financial math on financial literacy, we provide a more in-depth insight in the evolution of individual students based on the transition matrix in Table 3. This matrix shows the number of units that a student's financial literacy score has increased or decreased compared with his/her initial result on the pretest. For instance, the last column shows that there were two students with a score of 18 on the pretest of which one has increased his/her score with one unit, while the other scored two items lower (i.e. they obtained a posttest score of 19 and 16 respectively).

Overall, most students (77.14%) increase their test result in the posttest. Except one, all of the 13 students that failed the pretest improve their result, although not always sufficiently to pass the posttest. Only a single student passed the pretest but failed the posttest. In unreported results, we perform a similar analysis for the subcategories 'Methods', 'Concepts' and 'Spillovers'. Overall, a similar picture emerges, except for 'Spillovers'. After the completion of the financial math course, more students increase their test scores, although the increase is somewhat less pronounced (average increase of 1 or 2 items). More students nevertheless pass in the posttest. For the category 'Spillovers' about 40% of the students remain at the same level. The number of students that passed the pretest in this category is however already quite high (72,61%)[(vi)], making the lack of progress somewhat less problematic. Nevertheless, if curriculum developers would like to address the financial literacy issues that are in the ‘Spillovers’ category, it follows that these issues should be dealt with in other courses in the curriculum, or alternatively, would require a revision of the current financial math learning plan.

Table 3. Transition matrix of individual students’ financial literacy scores

Difference between post- and pretest scoring \ Financial literacy score in pretest	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10	1													
9														
8														
7			1											
6					1	1	2							
5			2				3			1				
4				1			1	1	1		1			
3				1	2		2	4	2		1	2		
2				1			3	1	2		1	2		
1						1	1	2	3	3	1		1	1
0							1	3			3			
-1										2	1		1	
-2						1						1		1
-3														
-4														
-5													1	
-6														
-7														
-8									1					

Note: n = number of students

Conclusions and discussion

In view of the need of scholarly initiatives to increase financial literacy, integrating financial education in existing courses appears to be the most realistic option in view of the overloaded curricula and lack of resources (OECD, 2014a). We contribute to this discussion by investigating the possible role of financial mathematics. Given the similarities of the approach to mathematics in the Flemish Community and other countries like the UK, our results may also be relevant for the development of financial literacy programmes in other countries. Results of our exploratory study are promising: Average financial literacy scores increase after the completion of a financial math course. The positive effect is not limited to a better understanding of math-technical aspects but also encompasses broader applications of the concepts to the financial world. In addition, female students benefit to a larger extent. This is encouraging in view of the evidence that female financial literacy levels are generally lower than those of their male peers (Chen & Volpe, 2002; Fonseca, Mullen, Zamarro, &

Zissimopoulos, 2012; Lusardi & Mitchell, 2008; Mahdavi & Horton, 2014). Financial mathematics could thus help to narrow the gender gap.

We acknowledge that this exploratory study does not provide a definite answer on this issue, but we hope that these initial results may spur further research to broaden our understanding on how financial literacy can be integrated in school curricula in general, and on the way that financial math can facilitate this process specifically. Firstly, additional quantitative research, based on financial math learning plans in different countries and examining larger sample sizes, would be welcome. The additional variation in relevant characteristics will help in providing a more fine-grained picture of the significant population characteristics. Secondly, we focus on a possible short-term effect, while effective financial literacy education needs also to generate long-term effects as well. Hence, retention studies would broaden our understanding on this issue. Thirdly, it remains unclear whether students' increased financial literacy scores actually affect their individual behaviour, i.e. taking more responsible financial decisions in their own best short- and long-term interests (Mandell, 2008b). Controlled experiments in which students are put into fictitious life situations (see, e.g., Carlin & Robinson, 2012) can reveal whether the financial knowledge students acquired in a school context leads to behavioural effects in real life. Fourthly, if financial math helps to increase financial literacy, we also need a better understanding of the way that this effect is generated. Hence, additional qualitative research that focuses on the actual learning processes and intermediating personal and psychological factors is warranted. By doing so, we would be able to maximize the possible effect for every individual student. In this respect it would also be interesting to examine how the learning environment and class differentiation could lead to further advancements in financial literacy for specific groups. Results in Renne (2001) on classroom math instruction suggest that such an approach could help girls in achieving equitable participation. In addition, it is also recommendable that specific attention would be devoted to the impact of teachers and the student-teacher relationship. Fowler and Poetter (2004), for instance, argue that the selection of competent teachers with significant mathematical knowledge is an important factor in the success of elementary math education in France. Fifthly, results indicate that financial math could be helpful, but is unlikely to provide an all-in-one solution to financial education at school.

Worded differently, financial math is likely to be helpful in a cross-curriculum approach of financial literacy, but not as a stand-alone solution. Hence, to arrive at a successful cross-curricular approach to financial literacy, increased knowledge on the overall framework (which course is most effective for a specific aspect of financial literacy) is needed. Increased insight in how these courses intertwine and reinforce each other would complete this strand of research. Based on this study, financial math is nevertheless likely to be an essential part in this knowledge network.

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Appendix

Financial literacy questions of the test sorted by the three categories (Answers are added between brackets)

Items relating to the category 'Methods'
Suppose you have € 1000 on your savings account that pays interest at 1% per year. How much money will be on the account after three years without withdrawing or depositing money?

- ❑ *Less than € 1030*
- ❑ *Just € 1030*
- ❑ *More than € 1030*
- ❑ *No idea*

(Answer: More than € 1030)

Last year you purchased a smartphone for € 200. Today, the same smartphone costs € 150. Which statement is correct?

- ❑ *The price of the smartphone has dropped by 25%.*
- ❑ *The price of the smartphone has dropped by 50%.*
- ❑ *The price of the smartphone has dropped by 75%.*
- ❑ *No idea*

(Answer: The price of the smartphone has dropped by 25%)

Suppose you borrow an amount of € 10 000 at an interest rate of 3%. You can choose to repay that amount on 5 or 10 years. When will you pay the highest amount of interest in total?

- ❑ *If you repay on 5 years*
- ❑ *It is the same in both cases*
- ❑ *If you repay on 10 years*
- ❑ *No idea*

(Answer: If you repay on 10 years)

You have a savings account with an annual interest rate of 2%. You deposit € 200 per year on this account. After ten years you check how much money there is in the account. That amount will be the highest if...

- ❑ *You always deposit the € 200 at the beginning of the year.*
- ❑ *You always deposit the € 200 at the end of the year.*
- ❑ *It doesn't matter if you deposit the € 200 at the beginning or at the end.*
- ❑ *No idea*

(Answer: You always deposit the € 200 at the beginning of the year)

You can invest € 1000 on compound interest at 2% per year or at 1% per semester (= 6 months). Which investment yields the most?

- ❑ *Both are equal.*
- ❑ *Interest at 1% per semester.*
- ❑ *Interest at 2% per year.*
- ❑ *No idea*

(Answer: Interest at 1% per semester)

Suppose you have two types of accounts to which you deposit € 200 once at the same time. Account A pays 2% simple interest per year, account B pays 2% compound interest per year. Which account has yielded the most after three years?

- ❑ *Account A has yielded more than account B.*
- ❑ *The two accounts yielded the same amount.*
- ❑ *Account B has yielded more than account A.*
- ❑ *No idea*

(Answer: Account B has yielded more than account A)

John and Susan each contract a loan of € 10 000 for the same term, namely 5 years, and the same annual interest rate of 3%. John opts for a type of loan with constant capital repayments and Susan for a loan with constant instalments. Who will pay the least amount of interest in total over the entire term of the contract?

- ❑ *In total John will pay less interest.*
- ❑ *In total both will pay the same amount of interest.*
- ❑ *In total Susan will pay less interest.*
- ❑ *No idea*

(Answer: In total John will pay less interest)

Items relating to the category 'Concepts'

Eva wants to buy a car but she hasn't enough money to pay the car directly. That's why she goes for a loan from her bank for which she has to pay each month an amount until the car is paid off. What is this?

- ❑ *A leasing*
- ❑ *An installment sale*
- ❑ *An installment loan*
- ❑ *No idea*

(Answer: An installment loan)

Interest on a savings account is …

- ❑ *An amount that you receive from the bank because you are a long-time customer.*
- ❑ *An amount that you have to pay to the bank because you deposit money on a savings account.*
- ❑ *An amount you receive from the bank because you deposit money on a savings account.*
- ❑ *No idea*

(Answer: An amount you receive from the bank because you deposit money on a savings account)

If you buy this, you actually lend money to your bank. As compensation for that money, your bank pays your interest at fixed moments during a certain term.

- ❑ *A savings certificate*
- ❑ *A government bond*
- ❑ *A share*
- ❑ *No idea*

(Answer: A savings certificate)

A loan in which a property, for example a house, is given as collateral. If the loan cannot be paid off, the property can be sold publicly. What type of loan is this?

- ❑ *An installment loan*
- ❑ *A mortgage loan*
- ❑ *A social loan*
- ❑ *No idea*

(Answer: A mortgage loan)

Which of the following statements about bank cards is <u>not</u> correct?

- ❑ *You can usually withdraw cash 24 hours a day.*
- ❑ *You can usually get information about your account balance at a cash dispenser.*
- ❑ *You can withdraw cash anywhere in the world without having to pay extra.*
- ❑ *No idea*

(Answer: You can withdraw cash anywhere in the world without having to pay extra)

An account that offers easy access to your money for your daily transactional needs. You can deposit money on it, but you can also transfer and withdraw money.

- ❑ *A checking account*
- ❑ *A savings account*
- ❑ *A certificate of deposit*
- ❑ *No idea*

(Answer: A checking account)

With a loan with constant capital repayments...

- ❑ *You pay off a fixed part of the capital every period, the interest you pay does vary every period.*
- ❑ *You pay each period the same amount of capital and the same amount of interest.*
- ❑ *You pay the same amount of interest every period, but the capital you repay varies every period.*
- ❑ *No idea*

(Answer: You pay off a fixed part of the capital every period, the interest you pay does vary every period)

Items relating to the category 'Spillovers'

If you are investing in a basket of shares of several companies, the risk is..... than if you invest in shares of just one company.

- ❑ *Higher*
- ❑ *Equal*
- ❑ *Lower*
- ❑ *No idea*

(Answer: Lower)

Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money on this account?

- ❑ *Less than today*
- ❑ *Exactly the same*
- ❑ *More than today*
- ❑ *No idea*

(Answer: Less than today)

If you buy a share of a company...

- ❑ *Then you become partly co-owner of that company.*
- ❑ *Then you provide a loan to that company.*
- ❑ *Then you receive favorable conditions on the products or services that this company sells.*
- ❑ *No idea*

(Answer: Then you become partly co-owner of that company)

Which of the following insurances is legally compulsory?

- ❑ *Hospitalization insurance*
- ❑ *Hospitalization and car insurance*
- ❑ *Car insurance*
- ❑ *No idea*

(Answer: Car insurance)

What is the first thing to do if your wallet with a bank card in it has been stolen?

- ❑ *You wait until money is withdrawn from your account. If so, submit a complaint to the police.*
- ❑ *You immediately call card stop to have your bank card blocked.*
- ❑ *Nothing, because they don't know your secret code anyway.*
- ❑ *No idea*

(Answer: You immediately call card stop to have your bank card blocked)

Which of the following investments has on average the highest risk?

- ❑ *Shares*
- ❑ *Bonds*
- ❑ *Savings accounts*
- ❑ *No idea*

(Answer: Shares)

You receive an e-mail with your bank as sender and with the message to check and complete your personal details. To do this, you must fill in a form asking for your account number and your secret code for internet banking. You must return this form by mail. What do you do?

- ❑ *You fill in the form and send it by e-mail.*
- ❑ *You check if the e-mail contains a virus.*
- ❑ *You do not respond to the e-mail but you may contact your bank.*
- ❑ *No idea*

(Answer: You do not respond to the e-mail but you may contact your bank)

Endnotes

(1) Research was carried out while Geert Van Campenhout was full-time employed by KU Leuven. The information and views in this article are those of the author and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

(i) OECD also points to the potential spillover effects to other household members and the larger community. An interesting case in point is the National Strategy for Financial Education (ENEF) financial education project in Brazil covering 868 public high schools and approximately 20 000 students. Zia (2013) reported important spillover effects for the students that participated in the sense that parents' financial knowledge improved. In addition parents also showed more positive financial behaviours like keeping household budgets and increased saving rates.

(ii) The details are beyond the scope of this article, but overall we can state that financial mathematics is included or excluded from the curriculum for the third degree of secondary education depending on the specific competent authority and prevalent educational model. If included, both mandatory and non-mandatory scenarios are found. For details, see De Win (2015).

(iii) Given that unreported results reveal no differences depending on the educational type followed by the students or the school that they attend, we do not report separate results for subgroups based on these characteristics.

(iv) One-way ANOVA analysis to test that the null hypothesis that the effect of financial algebra on the three categories is identical has a p-value of <0.001. The post-hoc Tukey HSD-test for 'Methods' and 'Concepts' has a p-value of 0.002 and <0.001, respectively.

(v) Hence, multivariate analyses where these variables are included as control variables are not conducted.

(vi) Only 4 of them (6.55%) do not pass the posttest.

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MEDITERRANEAN JOURNAL FOR
RESEARCH IN MATHEMATICS EDUCATION

Volume 16 2019

CYPRUS MATHEMATICAL SOCIETY
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