SSHJ Everant ISSN-2456-2653

http://sshj.in/index.php/sshj/

Research Article

Social Science and Humanities Journal

CrossMark

Impact of educational software use in correlation with students' math performance

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Abstract: *- Information and Communication Technology (ICT) offers the opportunity for a rigorous approach of math concepts, by activating more senses and increasing at the same time the motivation for learning. However, appropriate adjustments of both the content and the teaching practice are required. These adjustments ensure a framework for the utilization of ICT. The research presented here is a quantitative empirical study=on the performance of sixth-grade students after the use of math educational software. The random sample, consisting of 42 students, and was drawn from the sixth-grade class of a public school. The software was used for 20 hours, to teach fractions to groups of four or five children at the computer classroom. Before and after the use of the software, the students took a test consisting of exercises on fractions. The results showed that after the use of math educational software, there was an improvement in the results of the mathematics test.*

Keywords: *- Math, Information and Communication Technology, educational software*

Introduction

Technological tools are used in primary education, as they facilitate and support computer-assisted learning. They offer the student the opportunity to acquire knowledge and learning experiences, through the several activities they support. For a technological tool to successfully support educational activities, it must: a) integrate various teaching strategies, b) allow the student exploration and interaction, and c) be as cross-thematic as possible. Therefore, technology should be incorporated in teaching and learning in ways which can provide educators with settings that support 21st century teaching methods (Organisation for Economic Co-operation and Development (OECD), 2015a).

Technology can enhance metacognition. Technological tools help students manage information in various ways e.g. improve assimilation, develop metacognition skills, and organize themselves in qualitative learning (Gurbin, 2015).

It is generally accepted that the use of computers or other Information and Communication Technology (ICT) in schools provides more opportunities to achieve a greater understanding of difficult concepts compared to traditional methods. Moreover, computers facilitate experimentation and exploration. They create positive beliefs regarding Mathematics. They offer the opportunity for cross-thematic approaches in Maths (Lavy & Shriki, 2010).

It is unquestionable that the use of educational software in the classroom activates the student reaction and participation in the educational process. At the same time, the software cannot be utilized creatively without the active presence of teachers.

The aim of this research is to test the conclusions of these previous statements in-depth. This research not only adds one more piece to the ICT puzzle concerning its educational use, but stimulates further research in this field. In this particular research, the use of educational software was chosen to investigate the improvement or not in the performance in Maths of sixth-grade students, particularly in fractions.

To evaluate the math educational software application, students were asked to complete two tests: one test before the application (pre-test) and one test after the application (post-test). The tests were designed to measure students' competence with fractions. For this purpose, the test exercises were drawn mainly from the international literature (see Appendix A).

The analysis of the results showed improvement in the grades of the Maths test, when teaching of fractions was supported by the educational software.

Literature review

The role of new technologies in education

Computers are now an integral part of everyday life, bringing about changes in the way people work and, more generally, in the way they live. The natural consequence of this fact is the change in the educational process and the skills that students have to cultivate (OECD, 2016).

Based on the literature (e.g. Smeets, 2005; Wachob, 2011; Azmi, 2017), a key element that makes the role of technology in education very important is that it creates conditions of autonomy and independence for students, so that they acquire an active rather than a passive role in the learning process. Besides, by incorporating computer activities, teachers have a powerful tool that can serve different needs and different learning styles. As Papert (1993) wrote "…computers would not simply improve school learning but support different ways of thinking and learning" (p. 178).

In general, the contribution of technology to the educational process is very important, as it creates motives for learning and activates participation, even for the "shy" students. It enhances students' engagement and commitment to learning, creates opportunities for more practice, develops social skills (e.g. ability to cooperate and communicate in class), and, finally, enhances self-esteem, among other things.

Nowadays, young people spend more time using ICT than was the case a few years ago (OECD, 2015a, 2015b). Nowadays, even on weekdays, teenagers average 2 hours daily on the computer playing games, texting on messenger and browsing the internet for information (OECD, 2015b). However, the transition from the non-formal uses of ICT to educational settings in school is not an easy task (Peterson, Dumont, Lafuente & Law, 2018).

An argument for using ICT in the context of education is that it could enhance learning. On the other hand, findings showed that ICT would not lead to auto-learning improvement. Instead, the use of ICT as a tool for instructional purposes (Tamim, Bernard, Borokhovski, Abrami & Schmid 2011) will deliver high learning outcomes. Of course, the child's natural curiosity along with continual access to information does not, unfortunately, result in learning improvement (Behar & Mishra, 2016). In order for ICT to help in achieving better learning results, educators with technical skills, willing to integrate new technology in teaching, are needed.

Meta-research of 110 published journal articles, written over 20 years, on the use of mobile devices (e.g. laptops) suggested a moderately positive effect on learning (Sung, Chang & Liu, 2016). Along the same lines, meta-studies of Fleischer (2012) and Zheng, Warschauer, Lin, and Chang (2016) on one-to-one computer programs in schools showed weak evidence of increased academic achievement and motivation, mostly in mathematics and few other subjects.

A meta-analysis by Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011) yielded higher performance in learning when technology was used to support students, so long as the guidance was typically given by expert teachers (Gerard, Matuk, McElhaney & Linn, 2015). Likewise, a meta-analysis by Li and Ranieri (2010) concluded that computer technology had positive effects on mathematics achievement, even more so when teachers used active and constructive approaches e.g. constructed knowledge through small-group computer activities.

Similarly, Kori, Pedaste, Leijen, and Mäeots (2014) claimed that, as long as the ICT technologies are appropriately incorporated in instruction, they could improve student's reflection. It is clear that when ICT had been integrated with the teacher's assistance, it was perfectly effective for deeper and meaningful learning in contrast with traditional settings without ICT. Hence, technology could complement and amplify the teacher's role in parallel with student's activation of complex cognitive processes.

Addressing the potential and benefits of technology requires time and energy, but so far, the Programme for International Student Assessment (PISA) outcomes indicated that even though some countries massively invested in technology, they didn't have the expected learning outcomes (OECD, 2015). Moreover, PISA suggested that ICT should be appropriately integrated into the classroom; otherwise there could be a pernicious impact on learning (Peterson, Dumont, Lafuente & Law, 2018).

Educational software

New educational technologies are now part of the educational process, and they have radically changed the way and form of teaching. The presence of technology in the classroom has increased dramatically. Computers, along with iPads and tablets, are everyday tools in most schools. New technologies have opened up new horizons in education concerning the learning process, allowing students to use multimedia software that addresses different thematic fields and adapts to the needs of all ages.

This advance has led to the development of specific programs and applications to assess students' academic progress. While most of these assessment tools can be used by all students, there are also features that are particularly useful for students with neurocognitive deficits (Lewandowski et al., 2016).

Figure 1 below illustrates the relationship between the two types of educational software, closed and open-source application methods, and the corresponding learning theory

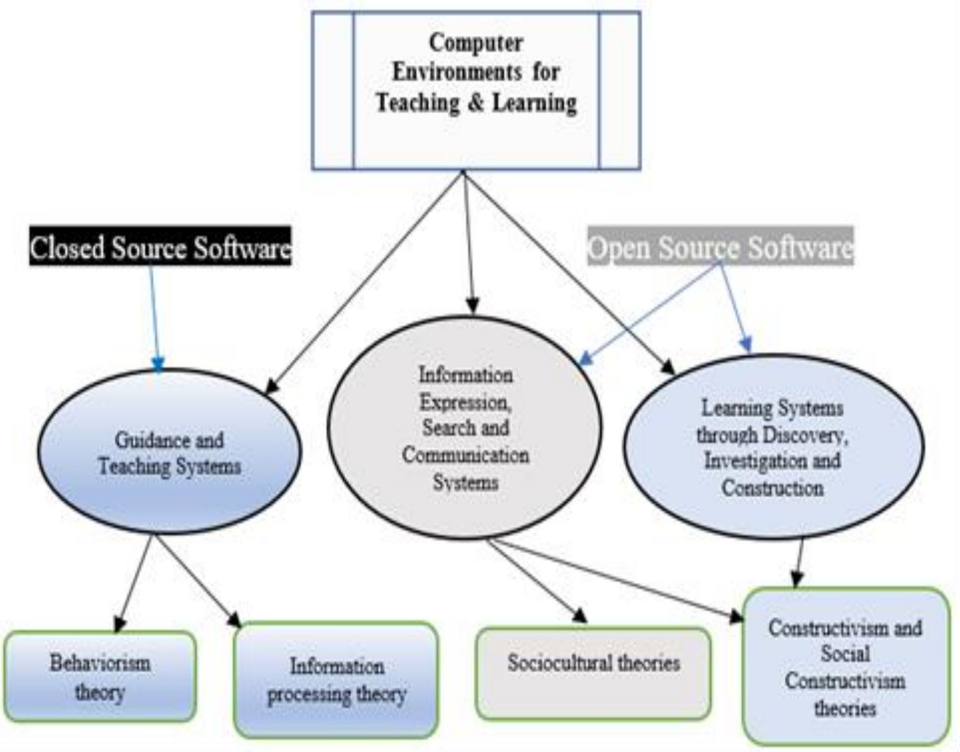


Figure 1. The relationship of educational software with learning theories

The educational software is aimed at (Sommerville, 2011):

- More appealing, rich and versatile presentation of the learning material
- A more experiential approach to knowledge
- The motivation of the student through creative activities, experimentation, and exploration
- Condensation of multiple lengthy texts in audiovisual messages of high information content
- Reduction of the student's time and effort to ingest the learning material
- Promotion of both the cooperative and the personalized learning

As Haelermans (2017) concluded in her study:

1. Studies conducted on the impact of computer-aided instruction compared to traditional classroom learning, where ICT complements the teacher, have found positive effects, though very low.
2. Regarding specific digital learning tools, positive effects have been detected in developing countries, both for mathematics and language classes. In western world countries, positive effects have been found only for mathematics, but not for language classes.
3. The effectiveness of ICT in education depends to a great extent on the way it is used and the pedagogical purpose it is intended to serve.
4. Many barriers are obstructing technological change for teachers, and this is probably the reason why technology has not yet been adopted in schools as effectively as expected.
5. Teachers are resisting technological change, in general, because of their beliefs and perceptions, or because of insufficient knowledge of how to apply technology in class in the most effective manner, or due to several factors such as lack of time, knowledge or training.

Delivering meaningful learning is an area that needs improvement in education. This can be achieved by using technologies most familiar to students (e.g. smartphone or tablet) in the classroom (Prieto, Palma, Tobías & León, 2019).

ICT in the teaching of Mathematics

Many educators are wondering how students comprehend the learning devices and how their use encourages learning Maths.

When technical tools are used within the framework of teaching, they aim to involve students in processes (practical and mental) which make sense inside the learning environment of the classroom. Thus, in conclusion, to use ICT as a teaching tool in teaching Math, the answer is the creation of proper teaching environments (UNESCO, 2012).

The educational use of the computer in teaching Math originated many years back with the creation of the logo environment by Papert (1980), a learning environment which offers students the ability to study the movements of a subject (turtle) on the computer screen. Thus, the creation of teaching and learning environments was triggered. This offered the student the opportunity to be involved in new interactions with the computer, and the ability to experiment and to test his/her ideas. In these environments, reflection, generalization, and deduction are possible, leading to the development of new logical-mathematical structures (Ruthven & Hennessy, 2002). Papert offered the opportunity to young students to unlock concepts that are considered to be extremely advanced for their age (Blikstein, 2013).

Furthermore, research by Sevari and Falahi (2018) on fifth-grade students, suggests that educational software has a positive impact on the performance of students in math. The integration of ICT by math teachers has been proven to significantly enhance students' progress. Be that as it may, the teacher will decide when, how and where he/she will use ICT, thus defining whether its use will facilitate students' learning of mathematics (Comi, Argentin, Gui, Origo & Pagani, 2017).

International research has shown that the use of developmentally appropriate technology provides significant opportunities for a differentiated, autonomous and customized learning (Beschorner & Hutchison, 2013). Within this framework, the appropriate applications play an important role, since they can provide unique possibilities for the enhancement of the notion of young children in abstract concepts via the presentation of dynamic representation and the inclusion of various interactive elements (Goodwin, 2012).

Not all applications have been designed according to the modern notions regarding effective pedagogical practice (Walsh, McGuinness, Sproule & Trew, 2010), so that their use will be beneficial for students of all ages, and particularly for young children. International research shows that children learn when they are cognitively active and involved in the learning process, when the learning experiences have meaning for them allowing the social interaction as well, and when learning is guided by a specific goal (Hirsh-Pasek et al., 2015).

The educational software that was used in our study was approved by the 'National Pedagogical Institute' (NPI), and it was created to constitute an environment of support for the learning and teaching of Maths for the Primary Education grades, according to the Curriculum. The educational software supports the area of Primary education Mathematics in various ways. The access provided by the software to the user (either student or teacher) has two levels. On the first level, every user can run the already existing activities.

On the second level, the user can create his/her activities either by using the software's websites or by developing a website. The website is able to integrate text, images, video, and sound, multiple-choice and right or wrong questions, as well as help, which contains instructions for the user.

Next Figure 2, illustrates the initial internet page of the math educational software (see Appendix D)

Figure 2. The math educational software

Methodology

The random sample of 42 sixth-grade students was drawn using a student list and selecting one student out of every three. The software designed by the PI on Maths was used complementarily for the teaching of the concept of fractions, fractions equivalence, and two operations of fractions: addition and subtraction.

For the application of the methodology, the students were divided randomly into groups of four or five children. The lessons were carried out in the computer classroom of the school.

To evaluate performance regarding operations of fractions, a test was given before the use of the software and another one after the use of the software. The tests comprise exercises/problems that evaluate the knowledge on fractions of every student in the sample. The tests score scale ranged from 1 to 20. On the 1st test, the students were asked to mark a number from one to 42, for anonymity. This number was shown to them by the researcher when they finished their test. They were asked to mark the same number on the 2nd test. The tests are shown in Appendix A.

The two tests were carefully constructed, linked to exercises/problems described in the international literature (Mack, 1990; ; Reys, Kim & Bay 1999; Burns, 2001; Sharp, Garofalo & Adams, 2002; Jigyel & Afamasaga-Fuata'I, 2007; Van de Walle, Folk, Karp & Bay-Williams, 2011) and properly fitted to this research (Appendix B).

To assess the change in score, the paired-samples t-test was the statistical procedure used (see Appendix C). The test was implemented in SPSS version 21 and Excel 2010.

Data Analysis

As shown in Figure 3, forty-two children agreed to participate in our research; 25 girls (59.52%) and 17 boys (40.48%).

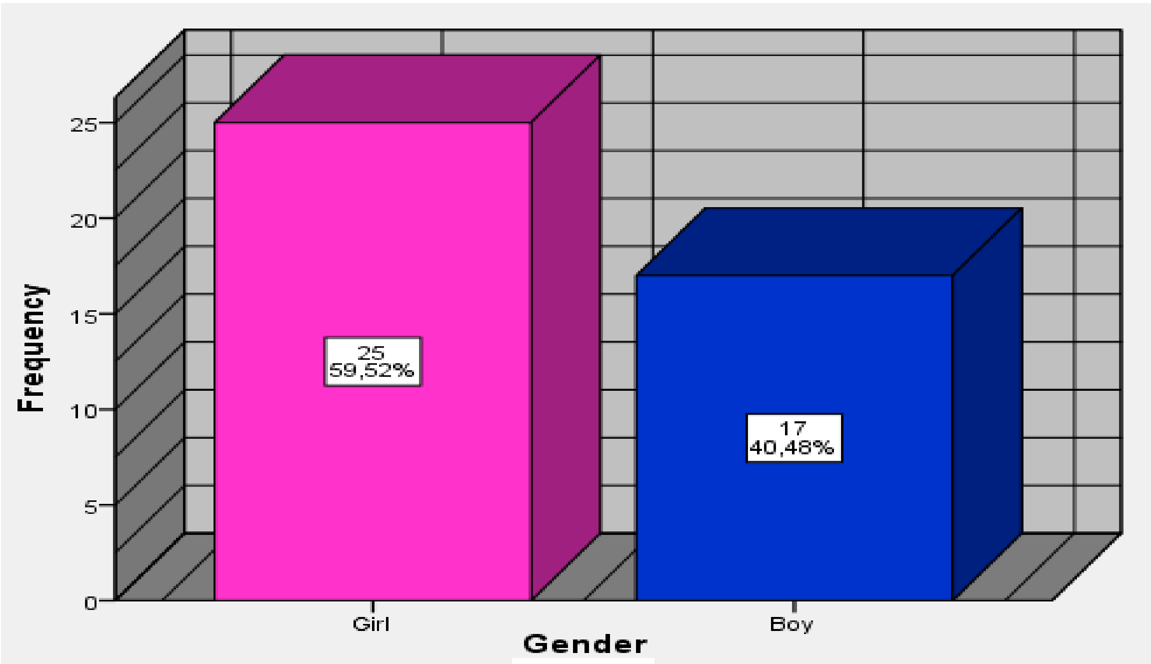


Figure 3. Gender percentages

The results of the normality test before and after the application of the method are presented below. An assumption of the paired sample t-test is that the difference in measurements follows the normal distribution. The Shapiro Wilk statistical test (N=42) was used. The three distributions were normal ($\alpha = 5\%$), more specifically $p = 0.08 > 0.05$ for the pre-test, $p = 0.15 > 0.05$ for the post-test and $p = 0.08 > 0.05$ for the difference of measurements (see Table). Moreover, no outliers detected.

Table *testing normality*

TEST	Sig.
PRE-TEST	0.08
POST -TEST	0.15
DIFFERENCE	0.08

The paired-samples t-test showed significant statistical variation between the measurements of the pre-test (M=12.98, SD=1.45, N=42), that was carried out before the methodology, and the measurements of the post-test (M=15.98, SD=2.18, N=42), that was given after the students were taught fractions via the math software with $t(41) = -13.58$, $p < 0.001$. The results indicate that, teaching fractions via the educational software improved the test scores.

The p-value of the two-tailed test was less than 0.05. Therefore, there is a statistically significant difference between the mean scores of the maths test for the use of ICT and not used ICT. The mean of the maths test score when using ICT was greater than the mean when ICT was not used. It can, therefore, be concluded that students are able to score significantly higher in the maths test when they use ICT than when ICT is not used.

Figure 4 shows the improvement in the score, produced by teaching fractions via the math educational software. More specifically, Figure 4 depicts the decrease in the low scores and the increase in the average and high scores.

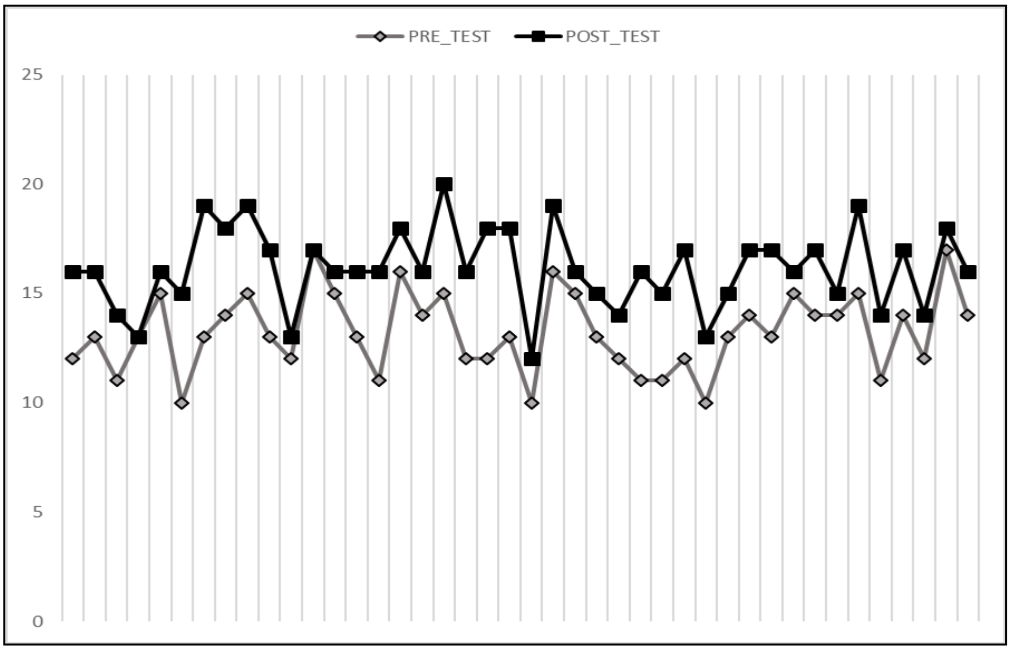


Figure 4. Grades of the two tests before and after the math software use

This conclusion is verified in Figure 5 below, which shows a decrease in the low grades after use of the math educational software, while at the same time there is an increase in the average and high grades.

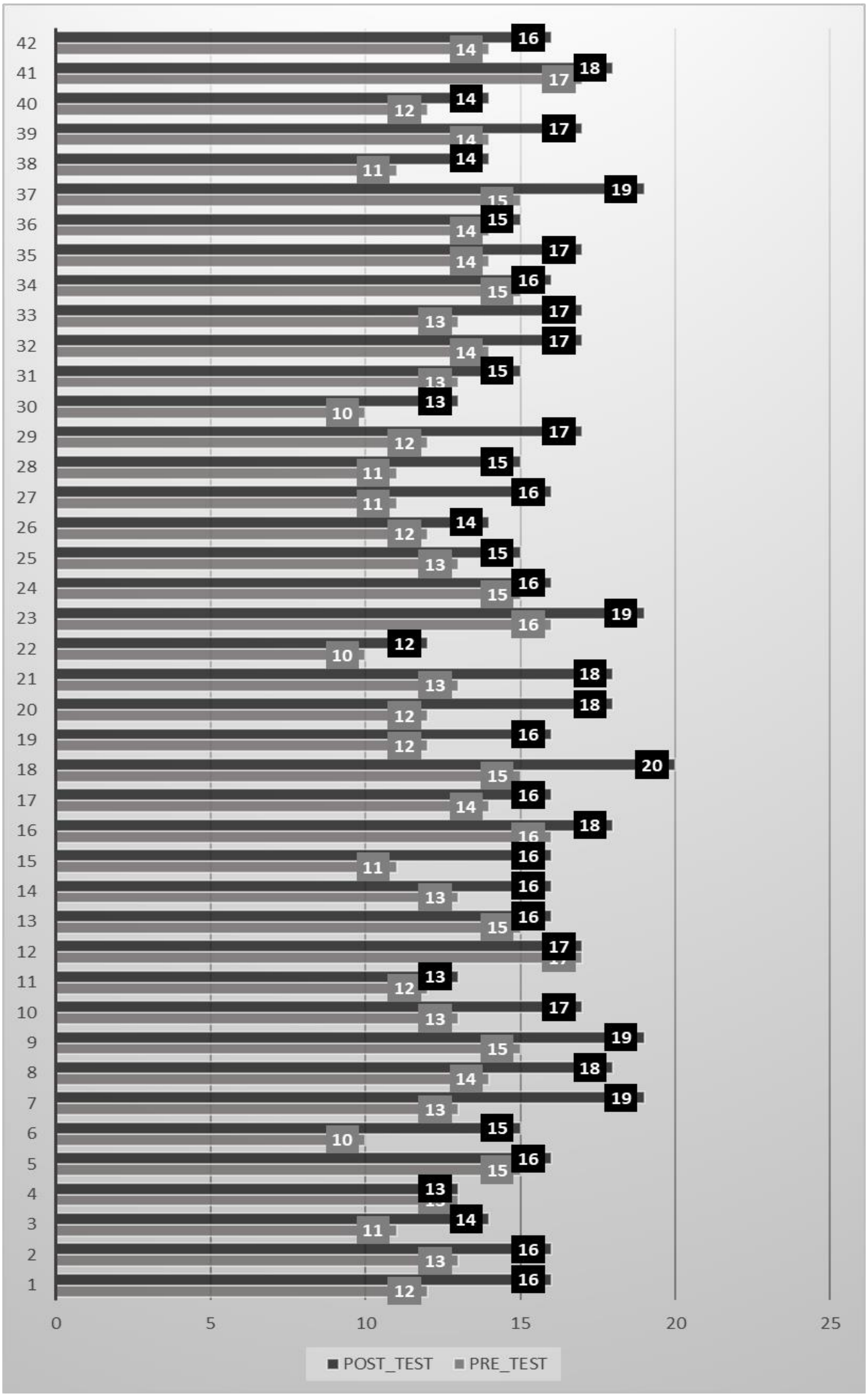


Figure 5. Comparison of the Pre and Post math test scores

Discussion and Conclusions

The literature review of the available research supports an optimistic view of the use of computers and other technologies in the classroom (Tamim, Bernard, Borokhovski, Abrami & Schmid 2011; Fleischer 2012; Kori, Pedaste, Leijen & Mäeots 2014; Sung, Chang & Liu, 2016; Zheng, Warschauer, Lin & Chang, 2016).

Those studies also demonstrated small outcome improvements to the massive investments in technology (OECD, 2018). Instead of impetuous investments in technology, it emerges more promising that technology applications should be integrated to support teacher instruction. Due to the fact that pedagogy is the key to effective learning design, policymakers should focus on how teachers integrate and use technology.

On the other hand, teachers should look to enhance technological pedagogical knowledge, as well as to generate educational innovation. The purpose of technology is to design and implement suitable pedagogies that use technologies to facilitate the learning needs of students. Thus, teachers have to proceed carefully with the integration of technology in education, because, as PISA found, it may have a pernicious impact on learning (Peterson, Dumont, Lafuente, & Law, 2018).

The results of this research were in agreement with the literature, and emphasized the utility of computer-aided math activities on the learning process and the benefits to the students from the integration of math software into the educational process (OECD, 2015; Gurbin, 2015; Sevari & Falahi 2018).

The bibliography of this review shows great promise in the use of math educational software, although many more rigorous studies are needed to develop an in-depth understanding of technology's uses in connection with instruction and learning.

More specifically this research indicates a significant improvement in knowledge acquisition and a consolidation of learning. Moreover, this research emphasized the utility of the NIP software and the necessity of math educational software in teaching math and fractions.

It is worth mentioning that, through teaching with the use of the particular math educational software, the learning and active participation of the students on the educational procedure was promoted. The students tested their hypothetical thinking; experimented; practiced questions with answers and explanations; communicated with each other, all of which led them to a better comprehension of fractions. Finally, the role of the teacher was differentiated. However, the training of the educator is a necessary prerequisite, both on the use of educational software and on the design of proper educational activities.

There is the possibility that the results might be biased, because the size of the sample was small. Thus, the results can be considered indicative but not definitive. Conducting further studies on other populations or under other conditions and criteria to replicate or refute our research would help define parameters for the use of math educational software. As we have not adjusted for potential confounding factors, we cannot be certain that the significant improvement in scores is caused by the use of the software.

Overall, the math educational software we used offered the opportunity for a rigorous approach on fractions through the better activation of senses, at the same time increasing the motivation for learning. However, appropriate adjustments of both the content and the teaching practice are required, to establish a framework for the utilization of ICT.

References

1. Azmi, N. (2017). The Benefits of Using ICT in the EFL Classroom: From Perceived Utility to Potential Challenges. *Journal of Educational and Social Research, 7*(1). 111-118. https://doi.org/10.5901/jesr.2017.v7n1p111
2. Behar, A., & Mishra, P. (2016). ICTs in schools: Why focusing policy and resources on educators, not children, will improve educational outcomes. In S. Dutta, T. Geiger

& B. Lanvin (Eds.), The Global Information Technology Report 2015: ICTs for Inclusive Growth (pp. 73-78). Geneva: The World Economic Forum & INSEAD. Retrieved from http://www3.weforum.org/docs/WEF_Global_IT_Report_2015.pdf.

3. Beschorner, B. & Hutchison, A. (2013). iPads as a literacy teaching tool in early childhood. *International Journal of Education in Mathematics, Science and Technology*, *1*(1), 16-24.

4. Blikstein, P. (2013). Digital Fabrication and 'Making' in Education: The Democratization of Invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of Machines, Makers and Inventors* (p. 203-221). Bielefeld: Transcript Publishers.

5. Burns, M. (2001). *Teaching arithmetic: Lessons for introducing fractions*. Sausalito, CA: Math Solutions.

6. Comi, S., Argentin, G., Gui, M., Origo, F. & Pagani, L. (2017). Is it the way they use it? Teacher, ICT and student achievement. Economics of Education Review, *56*, 24-39. https://doi.org/10.1016/j.econedurev.2016.11.007

7. Fleischer, H. (2012). What is our current understanding of one-to-one computer projects: A systematic narrative research review. *Educational Research Review*, *7*(2), 107-122. https://doi.org/10.1016/j.edurev.2011.11.004

8. Gerard, L. F., Matuk, C. F., McElhaney, K. W., & Linn, M. C. (2015). Automated, adaptive guidance for K-12 education. *Educational Research Review*, *15*, 41–58. https://doi.org/10.1016/j.edurev.2015.04.001

9. Goodwin, A. L. (2012). Teaching as a profession: Are we there yet? In C. Day (Ed.), *The Routledge International Handbook of Teacher and School Development* (pp. 44-56). Abingdon, UK: Taylor & Francis.

10. Gurbin, T. (2015). Metacognition and Technology Adoption: Exploring Influences. *Procedia - Social and Behavioral Sciences*, *191*, 1576-1582, https://doi.org/10.1016/j.sbspro.2015.04.608

11. Haelermans C. (2017). Digital Tools in Education: On Usage, Effects and the Role of the Teacher. Stockholm: SNS Förlag. Retrieved from https://www.sns.se/wp-content/uploads/2017/10/digital-tools-in-education.pdf.

12. Hirsh-Pasek, K., Zosh, J., Golinkoff, R., Gray, J., Robb, M., & Kaufman, J. (2015). Putting Education in "Educational" Apps: Lessons From the Science of Learning. *Psychological Science in the Public Interest*, *16*(1), 3–34. https://doi.org/10.1177/1529100615569721

13. Jigyel, K. & Afamasaga-Fuata'i, K. (2007). Students' Conceptions of Models of Fractions and Equivalence. *Australian Mathematics Teacher*, *63* (4), 17-25.

14. Kori, K., Pedaste, M., Leijen, Ä., & Mäeots, .M. (2014). Supporting reflection in technology-enhanced learning. *Educational Research Review*, *11*, 45-55. https://doi.org/10.1016/j.edurev.2013.11.003

15. Li, Y. & Ranieri, M. (2010). Are 'digital natives' really digitally competent? —A study on Chinese teenagers. *British Journal of Educational Technology*, *41*(6),1029-1042. https://doi.org/10.1111/j.1467-8535.2009.01053.x

16. Lewandowski, K., Sperry, S., Ongur D., Cohen, B., Lesley, N., & Keshavan, M. (2016). Cognitive remediation versus active computer control in bipolar disorder with psychosis: study protocol for a randomized controlled trial. *BMC*, *17*(1), 136-156. https://doi.org/10.1186/s13063-016-1275-7

17. Lavy, I., & Shriki, A. (2010). Engaging in problem-posing activities in a dynamic geometry setting and the development of prospective teachers' mathematical knowledge. *Journal of Mathematical Behavior*, *29*(1), 11-24. https://doi.org/10.1016/j.jmathb.2009.12.002

18. Mack, N. K. (1990). Learning fractions with understanding: Building on informal knowledge. *Journal for Research in Mathematics Education*, *21*(1), 16-32. https://doi.org/10.2307/749454

19. OECD (2015a). *New approach needed to deliver on technology's potential in schools*. Paris: OECD Publishing.

20. OECD (2015b). *Students, Computers and Learning: Making the Connection*. Paris: OECD Publishing.

21. OECD (2016*). Education at a Glance 2016: OECD Indicators*. Paris: OECD Publishing.

22. Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books, Inc.

23. Papert, S. (1993). *The Children's Machine: Rethinking School in the Age of the Computer*. New York: Basic Books, Inc.

24. Peterson, A., Dumont, H., Lafuente, M., & Law, N. (2018). Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning. https://doi.org/10.1787/9f843a6e-en.

25. Prieto, C. M., Palma, L. O., Tobías, B.P.J., & León, F.J.M. (2019). Student Assessment of the Use of Kahoot in the Learning Process of Science and Mathematics. *Education Sciences*, *9*(1), 55. https://doi.org/10.3390/educsci9010055

26. Reys, B.J., Kim, O., & Bay, J.M. (1999). Establishing fraction benchmarks. Mathematics. *Teaching in the Middle School*, *4*(8), 530-532.

27. Ruthven, K. & Hennessy, S. (2002). A practitioner model of the use of computer-based tools and resources to support mathematics teaching and learning. *Educational Studies in Mathematics*, *49* (1), 47-88. Retrieved from https://www.educ.cam.ac.uk/research/projects/istl/WP021.pdf.

28. Sharp, J. M., Garofalo, J., & Adams, B. (2002). Children's development of meaningful fraction algorithms: A kid's cookies and a puppy's pills. In B. Litwiller, & G. Bright (Eds.), *Making sense of fractions, ratios and proportions* (pp. 18-28). Virginia: National Council of Teachers of Mathematics.

29. Sevari, K. & Falahi, M. (2018). The Effectiveness of Math Educational Software on Creativity and Academic Performance. *Psychology & Behavioral Science International Journal*, *8*(4). Retrieved from https://juniperpublishers.com/pbsij/PBSIJ.MS.ID.555741.php

30. Smeets, E. (2005). Does ICT contribute to powerful learning environments in primary education? *Computers & Education*, *44*(3), 343-355. https://doi.org/10.1016/j.compedu.2004.04.003

31. Sommerville, I. (2011). SOFTWARE ENGINEERING (9th Ed.). https://www.academia.edu/7994405/Software_Engineering_9th_edition_I._Sommerville_Pearson_2011_BBS

32. Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, *94*, 252-275. http://dx.doi.org/10.1016/j.compedu.2015.11.008

33. Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What Forty Years of Research Says About the Impact of Technology on Learning: A Second-Order Meta-Analysis and Validation Study.

Review of Educational Research, *81*(1), 4–28. https://doi.org/10.3102/0034654310393361

34. UNESCO (2012). ICT in Primary Education. Exploring the origins, settings and initiatives. http://iite.unesco.org/pics/publications/en/files/3214707.pdf

35. Van de Walle, J. A., Folk, S., Karp, K.S., & Bay-Williams, J. M. (2011). *Elementary and middle school mathematics: Teaching developmentally* (3rd Can. ed.). Toronto: Pearson.

36. Wachob, P. (2011). Critical Friendship Circles: the cultural challenge of cool feedback. *Professional Development in Education*, *37*(3), 353-372. https://doi.org/10.1080/19415257.2010.537064

37. Walsh, G., McGuinness, C., Sproule, L. & Trew, K. (2010). Implementing a play-based and developmentally appropriate curriculum in NI primary schools:what lessons have we learned? *Early Years: An International Research Journal*, *30*(1), 53-66. https://doi.org/10.1080/09575140903442994

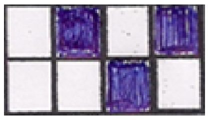
38. Zheng, B., Warschauer, M., Lin, C.-H., & Chang, C. (2016). Learning in One-to-One Laptop Environments: A Meta-Analysis and Research Synthesis. Review of Educational Research, 86(4), 1052–1084. https://doi.org/10.3102/0034654316628645

Appendix A

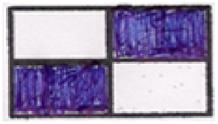
TEST_PRIN (PRO)

Complete the fractions that are missing in the following sentences. Both cakes have the same size. Pieces in blue are the ones that have eaten.

1. John ate ☐/☐ of the cake →



2. Maria ate ☐/☐ of the cake →



3.Which one (John or Maria) ate more?

....

Explain why.

....

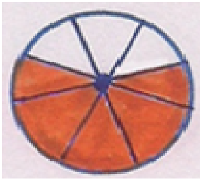
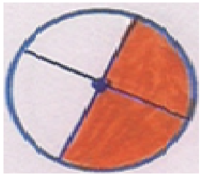
....

....

4.The pieces that both ate model the whole cake. T. F.

TEST_META

1. What fraction of the pizza Maria and Helen ate:

A. Maria: ☐/☐  B. Helen: ☐/☐ 

2. Which one (Maria or Helen) ate more?..

Explain why:..

....

....

3. Adding the fraction of the pizza that Maria ate and the fraction of the pizza that Helen ate would result in a fraction bigger than one pizza; ....

Calculate: ....

....

Explain : ....

....

4. The denominator in Maria's fraction tells us that the pizza was cut into 8 pieces.
T. F.

Appendix B

1. There are 4 kids at a party and there are 7 brownies for them to share.
   How can they share them? (Sharp et al., 2002 p. 20)

2. Does 4/6 = 2/3? How do you know?
   (adapted from Van de Walle et al., 2011, p. 310)

3. Subtract: 4 – 7/8 (Mack, 1990, p. 24)

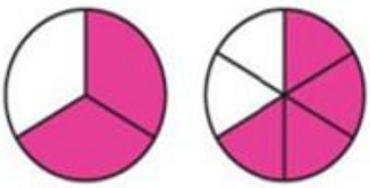
4. Which fraction is bigger, 1/6 or 1/8? Explain your answer. (Mack, 1990, p. 22)

5. Which is larger, 6/8 or 4/5? Explain your reasoning. (Burns, 2001, p. 137)

6. Is the following sum larger or smaller than 1? Explain how you know. Use estimation.
   3/8 + 4/9 (Reys et al., 1999, p. 530)

7. Is the following sum larger or smaller than 1? Explain how you know. Use estimation.
   ½ + 1/3 (Reys et al., 1999, p. 530)

8. Are the following shaded circles equal? Compare and explain your answer.
   (Jigyel & Afamasaga-Fuata'i, 2007, p. 21)



Appendix C

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PRE_TEST	,149	42	,019	,953	42	,082
POST_TEST	,147	42	,023	,960	42	,152
Difference	,167	42	,005	,953	42	,081

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE_TEST	12,98	42	1,456	,225
	POST_TEST	15,98	42	2,181	,336

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PRE_TEST & POST_TEST	42	,760	,000

Paired Samples Test

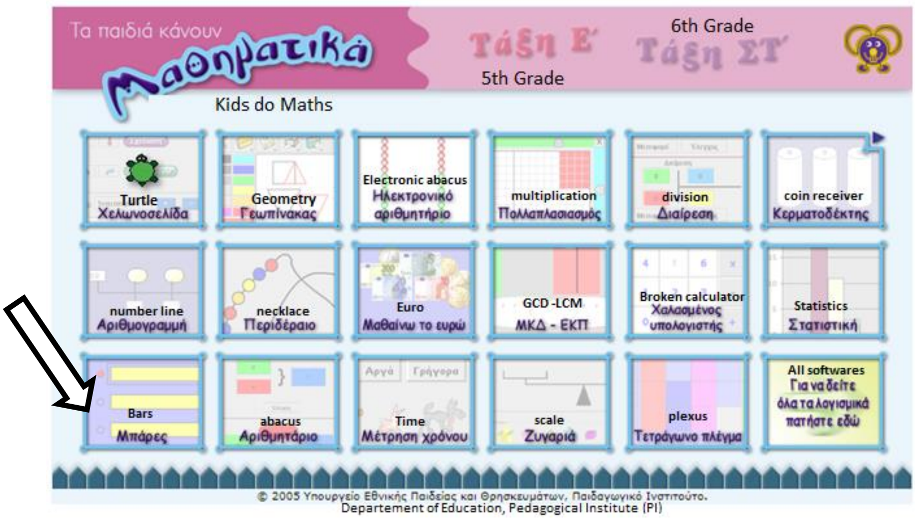
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	PRE_TEST - POST_TEST	-3,000	1,431	,221	-3,446	-2,554	-13,583	41	,000

Appendix D

Example: Using the software to compare fractions.

1. Find which fraction $\frac{1}{4}$, $\frac{2}{6}$, $\frac{2}{12}$ is larger ?
2. Arrange the fractions in ascending order using the symbol "<".
3. Kostas, George and Paul took part in their school race. In 5 minutes Kostas covered $\frac{1}{4}$ of the distance, George covered $\frac{2}{6}$ of the distance and Paul $\frac{2}{12}$ of the distance. Who covered the longest distance?

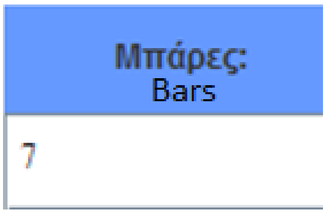
1. First step. Open the software "Kids do maths" of PI and left-click on the Bar square



- **Step 2.** At the top left of the software screen is the Bar icon.

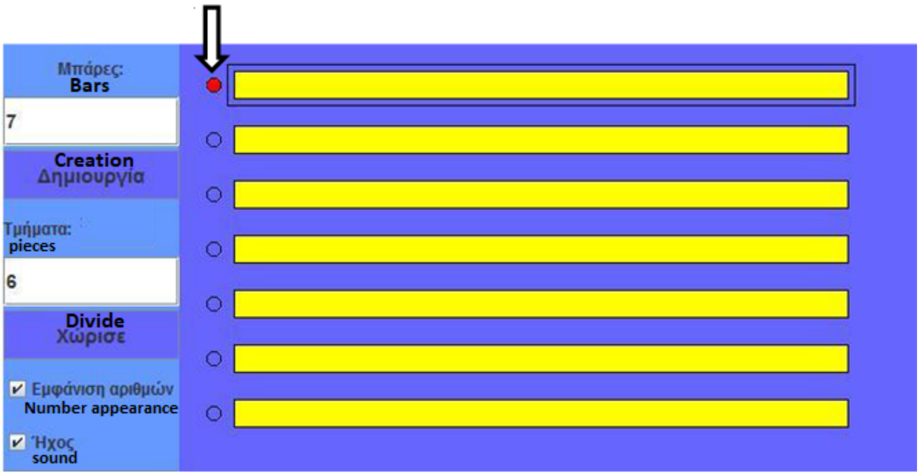
- **Step 3.** Place the mouse pointer  in the white rectangle. The pointer turns to cursor (I). Left-double-click to blacken 6.

- **Step 4.** Enter number 7.

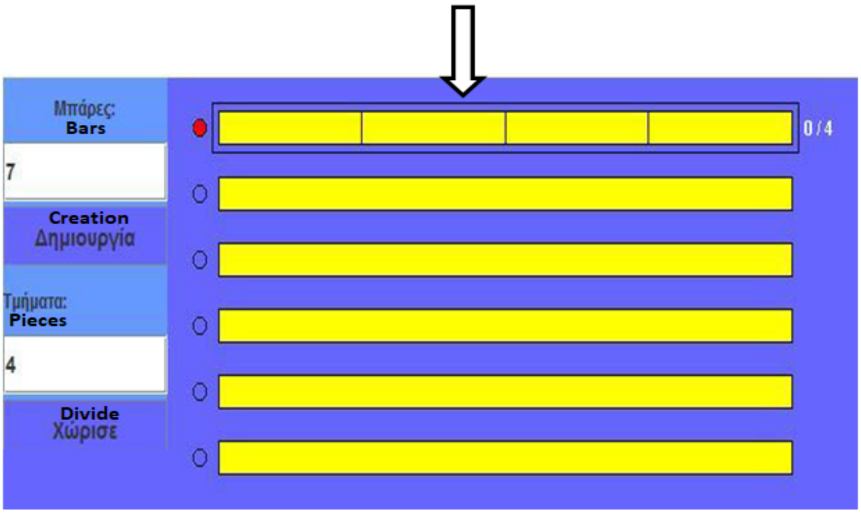


- **Step 5.** Click on the word icon "Creation"

There are 7 bars on your screen, only one of which has a red circle on its left.

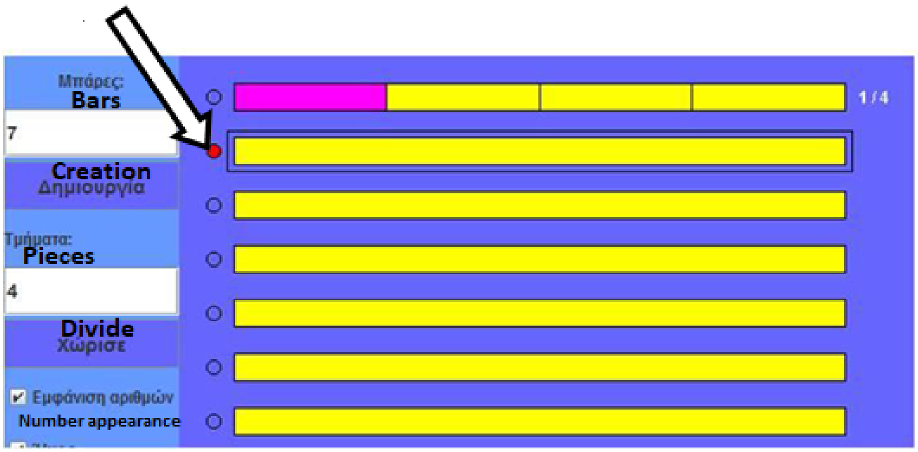


- **Step 6**. In the white rectangular under "Pieces" enter 4 instead of 6.
- **Step 7.** Click "Divide". The red dot bar is divided into four (4) pieces.

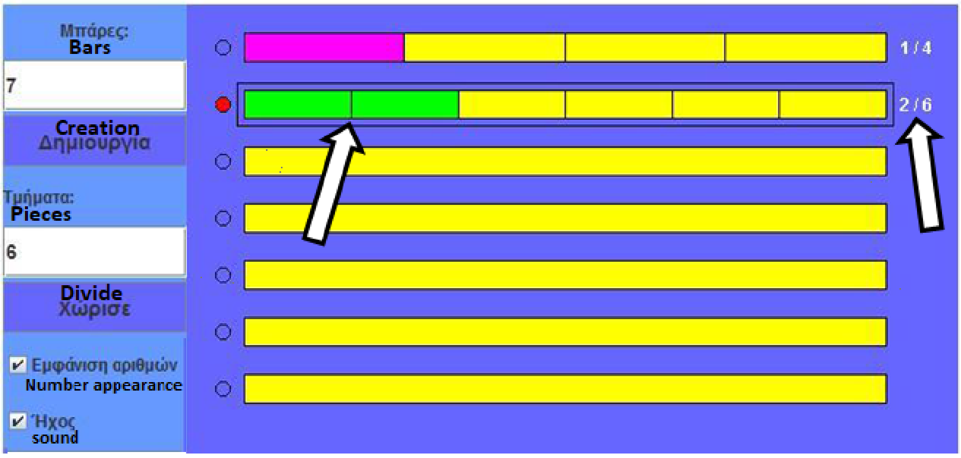


- **Step 8.** Click on the first bar, then one piece changes color from yellow to pink. The fraction from $\frac{0}{4}$ turns to $\frac{1}{4}$ at the end of the first bar.

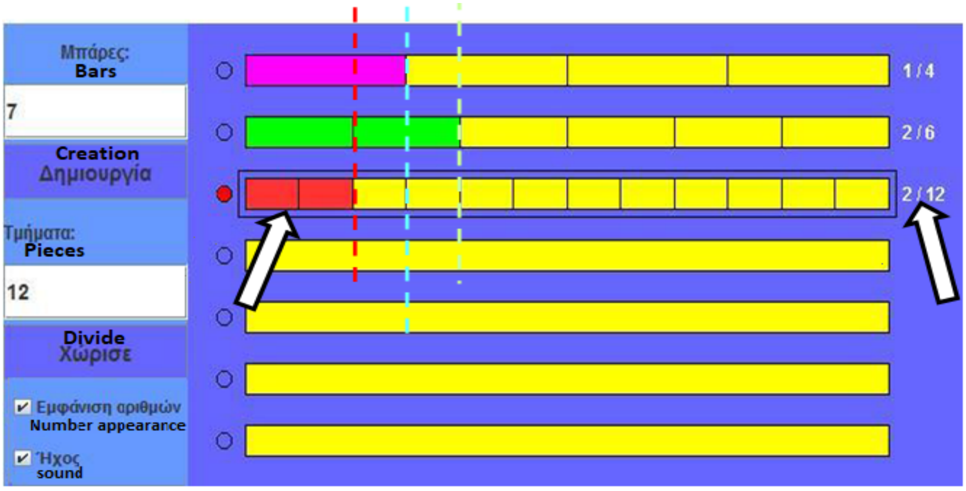
- **Step 9.** Click on the red dot at the beginning of the second bar.



- **Step 10.** On the second bar the fraction $\frac{2}{6}$ is constructed. Repeat steps **6** through **8**. $\frac{0}{6}$ Changes to $\frac{1}{6}$, then click on the second piece of the same bar, the fraction $\frac{1}{6}$ changes to $\frac{2}{6}$ at the end of the second bar.



- **Step 11.** Click on the red dot next to the third bar.
- **Step 12.** On the third bar the fraction $\frac{2}{12}$ is constructed. Repeat steps 6 through 8. Divide the third bar into twelve pieces and click on two pieces.



Answer:

At this point we find that the larger fraction is $\frac{2}{6}$ and the ascending order is $\frac{2}{12} < \frac{1}{4} < \frac{2}{6}$.

Assigning the first bar to Costas, the second Bar to George and the third bar to Paul we find that George covered the longest distance.