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# Developing Mathematical Resilience: Students' Voice About the Use of ICT in Classroom

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# Abstract

**Introduction.** Mathematical resilience is assumed as one of the most important areas in school context and whose focus should be given priority, due to the distress exhibited by students when learning and understanding basic knowledge in mathematics year after year. The main goal of this research was to study how students attending middle schools in the suburban area of the Portuguese capital are able to recognize and express mathematical resilience characteristics after solving several tasks in groups using ICT.

**Method.** This research was conducted with 64 students from the 8th grade, from three socio-economic disadvantaged schools, who answered a short open-ended questionnaire regarding their experience in working on a sequence of three articulated tasks in the mathematics classroom, with the use of ICT. Different categories and subcategories have emerged from the conducted inductive content analysis.

**Results.** The results of this study suggest students perceived the experience of using ICT in their mathematics lessons as useful for their learning process and appreciated to enroll tasks through a practical teaching-learning environment. Students also highlighted the importance of their peers' support and perceived *TinkerPlots* software as a useful tool to enhance their understanding and learning of mathematical concepts, pointing how this learning experience became more interesting and easy to them. Nevertheless, a residual number of students reported feelings of distress whilst others indifference.

**Discussion and Conclusion.** The results of this research suggest these students exhibit some characteristics the specialized literature has pointed as typical from mathematical resilient students. Some implications for school practitioners are formulated but further research is needed to enlarge the understanding of how ICT tools in certain environments can be effective to enhance students' learning while promoting mathematical resilient behaviors.



**Keywords:** Mathematical resilience, ICT, *TinkerPlots*, Students' voice, Learning

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# El desarrollo de la capacidad de resiliencia matemática: La voz de los estudiantes sobre el uso de las TIC en la aula

## Resumen

**Introducción.** La resiliencia matemática se asume como uno de los temas más importantes en el contexto escolar y la atención al respecto ha de ser prioritaria, dada la angustia exhibida por los estudiantes en el aprendizaje y las dificultades de comprensión de los conocimientos básicos en matemáticas año tras año. El objetivo principal de esta investigación fue el estudio de cómo los estudiantes que asisten a escuelas intermedias en el área suburbana de la capital portuguesa son capaces de reconocer y expresar las características de resiliencia matemática después de resolver varias tareas en grupos utilizando las TIC.

**Método.** La investigación se realizó con 64 estudiantes del octavo grado, de tres escuelas en desventaja socioeconómica, que respondieron a un cuestionario breve de composición abierta sobre su experiencia en el trabajo en una secuencia de tres tareas desarrolladas en el aula de matemáticas, con el uso de las TIC. Diferentes categorías y subcategorías han surgido a través del análisis de contenido inductivo realizado.

**Resultados.** Los resultados sugieren que los estudiantes perciben la experiencia del uso de las TIC en sus clases de matemáticas como útiles para su proceso de aprendizaje y que apreciaban a resolver tareas a través de un entorno de enseñanza-aprendizaje práctico. Los estudiantes también destacaron la importancia del apoyo de sus pares y del software *TinkerPlots,* percibido como una herramienta útil para mejorar su comprensión de conceptos matemáticos y el aprendizaje y que ha propiciado que esta experiencia de aprendizaje resultara más interesante y accesible para ellos. Sin embargo, un número residual de los estudiantes manisfestó sentimientos de angustia, mientras que otros la indiferencia.

**Discusión y Conclusión.** Los resultados de esta investigación sugieren que estos alumnos presentan algunas características que la literatura especializada indica como típicas de los estudiantes con resiliencia matemática. Se exponen algunas implicaciones para educadores educativos, redundando en la necesidade de más investigaciones para ampliar la comprensión de cómo las herramientas TIC en ciertos ambientes pueden ser eficaces para mejorar el aprendizagem de los estudiantes mientras promueven conductas resilientes en las matemáticas.

**Palabras Clave:** Resiliencia matemática, las TIC, *TinkerPlots*, Voz de los estudiantes, Aprendizaje

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## Introduction

Resilience is a classic construct from Educational Psychology and has been the main focus of several researches in the last ten decades (e.g., Luthar, 2007). Resilience can be defined as "any behavioral, attributional, or emotional response to an academic or social challenge that is positive and beneficial for development" (Yeager & Dweck, 2012, p.303).

Although resilience has been extensively studied with children and youths living in risk settings (e.g., drugs, violence, poverty), the research developed with children and youths living in normative contexts is scarce. As a matter of fact, if understanding how children and youths living in risk settings has a vital importance to help them to develop success despite the adversity they face in their daily life, it is also important to enlarge the knowledge and understanding of how to help youths from normative contexts to develop successful educational pathways.

Given the multidimensional and complex nature of resilience it becomes important to analyze and understand this construct in specific contexts (Luthar, 2007). Mathematical resilience is assumed as one of the central areas in school context and whose focus should be given priority, taking into account the distress exhibited by students when learning and understanding basic mathematical knowledge in classrooms year after year. In Portugal, mathematics is one of the most feared subjects and in which academic performance is more problematic. As it happens in our national context, statistics is one domain in the mathematics subject for all grades from elementary to secondary school in many countries and therefore students conceive it as one of the themes they have to learn in mathematics. As this theme is often taught simply as a list of procedures and graphs to construct and its specific nature is not considered, a project has been developed in order to help students to understand the purpose and utility of data in meaning making of the real-world, by proposing more demanding tasks using Information and Communication Technology (ICT; Henriques & Oliveira, 2016).

This research was developed in the context of the above project and focuses in the particular domain of mathematical resilience. Its main goal is to understand how middle school students are able to recognize and exhibit mathematical resilience characteristics after solving tasks using specific software in the theme of statistics. This research is a first-time approach to research developed worldwide regarding this issue, carried out in the domain of statistics education for middle school grades, with Portuguese students from socioeconomic disadvantaged school contexts which represent the normative educational pathways in suburban schools in the Lisbon area.

*Mathematical Resilience*

Mathematics is perceived by students as one of the most demanding and problematic school subjects and quite often in which academic performance is compromised early on the beginning of each new school year. Students may face difficulties in mathematics due to several reasons and in different concepts, being also diverse the strategies each one adopts to cope with them (González-Torres & Artuch-Ragarde, 2014; Lee & Johnston-Wilder, 2013). How can we then distinguish students that become anxious when facing demanding mathematical reasoning situations and avoid or refuse to engage in those tasks, from those who take a mathematical problem to challenge them and develop their skills and knowledge? Mathematical resilience is the psychological construct that can better explain the behavior individuals adopt when facing challenging and less favorable situations, yet achieving success (Lee & Johnston-Wilder, 2013).

Mathematical resilience assumes a positive Psychology approach and features those who are able to exceed affective barriers in their learning process. Students who are mathematically resilient easily adapt and are able to cope with arduous, ambiguous situations despite the barriers they face (Lee & Johnston-Wilder, 2013). These students have a growth mindset as they know they have the strength needed to overcome academic and non-academic adversities. Having a growth mindset means that students are able to make decisions with agency inside the classroom, experience themselves as part of the school community, and perceive themselves as part of the learning process (Dweck, 2000). In such classroom setting, students tend to feel save and persevere even when facing difficulties as they acquire communication skills and vocabulary to express their mathematical understandings (Yeager & Dweck, 2012).

According to Lee and Johnston-Wilder (2014), students who are mathematically resilient (i) believe that the ability to learn and master mathematical concepts is not static and restricted to few individuals, and that anyone can enlarge their skills and become better in mathematics; (ii) understand the instrumentality of mathematics, in other words, recognize its value in their daily life inside and outside academic context; (iii) understand that in order to develop mathematical concepts, effort, perseverance and curiosity are required; and (iv) recognize the importance of significant others, such as teachers or their peers, as well as tools such as ICT, in the support they need..

Previous research suggest the importance of intentionally promote mathematical resilience inside classrooms to enhance students' performance in the subject (e.g., Johnston-Wilder & Lee, 2010; Yeager & Dweck, 2012); this intentionality is needed for all students but especially for those who have deepest distress and are at risk of academic failure (Rivera & Waxman, 2011).

In this paper, we rely on students' voice as a point of departure to understand how mathematical resilience could be improved and, consequently, how mathematics learning could be enhanced. Students' voice has been recognized as a powerful source for collecting information regarding educational issues, as it offers powerful insights to teachers concerning students' learning experiences and opportunities for students' effective learning enhancement (e.g., Deaney, Ruthven, & Hennessy, 2003; Flutter, 2007; Lee & Johnston-Wilder, 2013). Whilst teachers become aware about what students feel and think while learning, they promote students' opportunities to assume agency in their own learning process (Flutter, 2007).

*Information and Communication Technology (ICT)*

In the last decade several studies have been conducted regarding the use of ICT in the teaching and learning in mathematics lessons (e.g., Fitzallen & Watson, 2010). Although the impact of ICT on students' mathematical resilience has not always been as expected (Lugalia, Johnston-Wilder, & Goodall, 2003), the majority of research found the use of these tools as effective in promoting students' resilient behaviors (Livingstone, 2012), since they reinforce the classroom participation, motivation to learn and performance in school tasks fulfillment (Deaney et al., 2003).

Although the importance of ICT in the teaching-learning process has been recognized, it should be noticed ICT *per se* does not enhance or improve the quality of that process (Sutherland et al., 2004). Resilience theories are based in an ecologic model and highlight the prominence of the contexts wherein the individual belongs and operates (Fergus & Zimmerman, 2005). In fact, it is important to realize the sociocultural influences of previous knowledge that teachers and students bring to each new learning situation, which has a strong influence in how the new knowledge will be developed (Kent & Facer, 2004). This premise reinforces the teacher's central role in how the mathematical activities are introduced with ICT, to ensure that all students can meaningfully learn (Deaney et al., 2003). As Moore (1997) pointed out, "the substantial change in statistics instruction is built on strong synergies between content, pedagogy, and technology" (p.123).

In the context of statistics education, some authors contend for the need to create a Statistical Reasoning Learning Environment (SRLE) where the tasks proposed to students have some underlying principles (Cobb & McClain, 2004; Garfield & Ben-Zvi, 2009). SRLE principles postulate that an advantaged learning environment occurs when classroom activities are designed to encourage students' reasoning and discourse, by using real and motivating data focused on central ideas, at the same time suitable technological tools and different assessment schemes are used (e.g., Garfield & Ben-Zvi, 2009).

*TinkerPlots* software is one of the technological tools used in such learning environments. It was designed to assist students in data exploration and statistical investigations. Its data visualization and modelling tools can be used from elementary grades since many of these tools are independent from specific content present in the school syllabus. Using a multiplicity of graphical representations with *TinkerPlots*, students can create unfamiliar plots and learn how to interpret data in an intuitive way and therefore gradually organize data to answer their questions (Konold & Miller, 2005).

This software was first released in 2004 and has been progressively updated based on the conducted research feedback. Several studies about its use in classroom have reached positive results and it has proved to be a useful tool for many teachers around the world (Ben-Zvi, 2006; Fitzallen, 2007; Garfield, delMas, & Zieffler, 2012; Henriques & Oliveira, 2016; Makar, Bakker, & Ben-Zvi, 2011; Watson, 2012).

*Aims*

The aim of this research is to study how students attending middle schools in the suburban area of the Portuguese capital are able to recognize and express mathematical resilience characteristics after solving several tasks in groups using ICT.

## Method

*Participants*

Participants were 64 students, 31 girls and 33 boys, between 13 and 16 years old, attending the 8th grade in three Portuguese public schools in the Lisbon area. These schools are located within suburban areas with disadvantaged socioeconomic conditions where multi ethnicity is prevalent; several of these students come from single-parent families and have school retention background. In these schools, it is estimated that at least 40% of students benefit of social financial support for school meals and textbooks and other school materials. None of these students have had previous experiences with ICT in their mathematics lessons.

*Instruments*

A short open-ended questionnaire was developed to access students' feedback regarding the activities they enrolled in the classroom using *TinkerPlots* software (Version 2.2). This questionnaire asked students to elect the tasks they most appreciated (which will not be object of analysis in this paper) and to answer four questions that were posed both in positive and negative form. For that reason, in this paper we better assume that students answered to a total of eight questions. The four questions posed in a positive form were: (i) "In your opinion, did the use of *TinkerPlots* to complete the tasks facilitate your statistical learning? If so, explain why."; (ii) "Which were the advantages of using *TinkerPlots* in the classroom?"; (iii) "What have you enjoyed the most when working with *TinkerPlots*?"; and (iv) "Did the group work help you to complete the tasks? Explain.". The four questions posed in a negative form were: (v) "In your opinion, did the use of *TinkerPlots* to complete the tasks facilitate your statistical learning? If not, explain why."; (vi) "Which were the disadvantages of using *TinkerPlots* in the classroom?"; (vii) "What have you enjoyed less in working with *TinkerPlots*?"; and (viii) "Did the group work not help you complete the tasks? Explain".

*Procedure*

Data were collected under a developmental research project untitled "Promoting Statistics Reasoning in Basic Education Using Technology", organized by the authors at the Institute of Education of the University of Lisbon. This project was developed with mathematics teachers from Basic Education and involved the planning and implementation of sequences of tasks, in their classrooms, targeting students' statistical reasoning. The students in their classes worked in groups of three or four and used *TinkerPlots* software (Version 2.2) to solve the tasks.

These tasks followed the basic principles of Cobb and McClain (2004) for the design of the sequences of tasks and the lessons' environment was based on SRLE principles (Garfield & Ben-Zvi, 2009; Henriques & Oliveira, 2016) with the underlying main goal of helping students to become statistically literate and able to think and reason about statistical information.

Three articulated tasks have been implemented in these classes, specifically: (i) *Nenana Ice Classic*, where students were asked to analyze different type of representations and make predictions based on real data available from the *TinkerPlots* database; (ii) *An Experience With Fish*, where students were involved in the process of decision making by comparing distributions using simulations provided by the *TinkerPlots* tools; and (iii) *The Human Body*, a statistical investigation to discover more about the students in their school, where they started by taking themselves their measures and then made informal judgments and predictions (Henriques & Oliveira, 2016).

By the end of the experience, students were asked to individually answer the short open-ended questionnaire developed for this research.

*Data Analysis*

An inductive content analysis was organized according to the three stages suggested by Bardin (2014), specifically: (i) pre-analysis, characterized by the first reading of the answers given by students with the aim to organize the information and reach a deeper understanding and familiarization with the written material; (ii) exploration, characterized by the categorization of the original data in context and registry units that are mutually exclusive, homogeneous, pertinent, objective, reliable, and productive; and (iii) data treatment, inference and interpretation, validated by three researchers who have independently reached an agreement regarding the exploration stage and the following steps.

Through content analysis different main categories arose, each one organized in several subcategories. The questions posed in a positive form were the ones that received the most input from students and originated three main categories and ten subcategories.

The category *Classroom* focuses in the issues related to the classroom environment transformation carried out by this experiment. Two subcategories were identified in this category: *Novelty* and *Groups. Novelty* is present when students express they enjoyed and valued the opportunity to learn in a non-traditional environment, different from the one they are used to. *Groups* regards how students have appreciated working with their peers over the tasks completion, and how they valued the mutual help performed by groups, argue with the peers and get to know each other opinions helped and motivated them in the learning process.

The category *Technology* focuses in the issues directly related with ICT inclusion in mathematics lessons, where books and exercises using paper and pencil were replaced by computers and *TinkerPlots* exploration. Four subcategories emerged: *Experience, Organization, Practical* and *Measures*. *Experience* respects students experiencing *TinkerPlots* as software to learn mathematics. *Organization* regards students' perception of the advantage *TinkerPlots* brings in adequately synthetize and organize noticeable data, and in displaying and managing intuitively the big amount of information resulting from data. *Practical* regards the practical nature of the work with *TinkerPlots* and how students enjoyed and valued to be able to manipulate data, to develop and do computations in a quicker, simple and straight forward way. *Measures* regards the reference students made to *TinkerPlots'* advantages in analyzing specific statistical measures such as the mean and median, an important statistical learning objective in this school grade.

The category *Learning* focuses on issues related with learning processes and environment. Four subcategories were identified: *Understanding, Knowledge, Easiness* and *Motivation*. *Understanding* regards students' perception of how using *TinkerPlots* for tasks completion enlarged their knowledge about statistical concepts helped them to better understand concepts previously presented in lessons and what they were asked to do in the tasks, and the possibility they have had to work autonomously in the tasks completion. *Knowledge* comprehends how using *TinkerPlots* helped students to learn new concepts or procedures that they did not know before. *Easiness* concerns students' perception of how *TinkerPlots* can be useful in their learning process by transforming exercises in an easy and more perceptive way to them. *Motivation* regards students' perceptions of how motivated they felt to engage in solving the tasks and to enhance their learning; "fun" and "interesting" were two adjectives they used to characterize these classes.

From the four questions posed in a negative form a total of four main categories and twelve subcategories have emerged.

The category *Technology* regards issues that students perceived as less pleasant in this experience, specifically in what concerns *TinkerPlots* software. This category is subdivided in five subcategories: *Manipulation, Instrumentality, Measures, Limitations* and *No disadvantages*. *Manipulation* regards students' lack of domain or familiarity with the new software. *Instrumentality* concerns the inability students seemed to show in considering this experience and the use of technology as part of the learning process and as a contribution to enhance their knowledge and skills. *Measures* encompass students' lack of appreciation for the use of *TinkerPlots* to calculate specific statistical measures. *Limitations* regards students' perception of *TinkerPlots* as a restricted software. *No disadvantages* denotes students' recognition of absence of disadvantages or weaknesses in using *TinkerPlots* to solve the tasks.

The category *Learning* focuses in issues related to students' willingness to learn or improve their knowledge, with two subcategories identified: *Interest* and *Knowledge*. *Interest* concerns students' willingness to learn along this experience. *Knowledge* includes students' perception that they already knew the targeted statistical content.

The category *Classroom* regards the perceived unpleasant consequences of the adopted teaching methodology in this experience. Two subcategories were identified: *Data collection* and *Environment*. *Data Collection* includes the discomfort students felt with matters directly related with the data collection performance. *Environment* regards the students' perception about unpleasant classroom physical conditions.

The category *Groups* regards the student's work with their peers in this experience. Three subcategories emerged: *Relationship*, *Work* and *Focus*. *Relationship* regards the discomfort some students felt in working with someone with whom they have lack of empathy or affinity. *Work* includes students' inability to organize the work with their peers and develop mutual support. *Focus* represents the situation where students did not focus on the work as the group was a source of disruption.

## Results

After developing content analysis on all students' answers based on the categories and subcategories indicated above, we produced tables 1 and 2 where we present an example of one student's answer for each subcategory in order to illustrate its meaning. We shall notice that some students answered incompletely to the questions (e.g., "Yes" or "No" with no further explanation); these answers were not included in any associated category or subcategory, but were considered as valid answers to the total number of answers (N) of each question.

***Table 1*. Classification of the Students' Answer to the Four Questions Posed in the Positive Form, by Categories and Subcategories**

| Question | Category | Subcategory | Examples |
|---|---|---|---|
| 1. "In your opinion, did the use of *TinkerPlots* to complete the tasks facilitate your statistical learning? If so, explain why." (N=46) | Classroom (n=4) | Novelty (n=4) | "Yes, because it was a different way to learn mathematics." |
| | | Groups (n=0) | |
| | Technology (n=45) | Experience (n=11) | "Yes, we can learn better using *TinkerPlots*." |
| | | Organization (n=7) | "Yes, because is much easier to organize everything." |
| | | Practical (n=8) | "…And I have preferred to do the computations in the computer and we can make graphs faster than by hand." |
| | | Measures (n=19) | "I guess so because the work was to learn the median, mean and mode." |
| | Learning (n=44) | Understanding (n=18) | "Yes, because I have never understood boxplots and through this software I was able to." |
| | | Knowledge (n=12) | "Yes, I did not know how to use statistics before and with *TinkerPlots* I have learned". |
| | | Easiness (n=10) | "It has greatly facilitated my learning with the graphs…" |
| | | Motivation (n=4) | "Yes, as it was fun I learned quickly." |
| 2. "Which were the advantages of using *TinkerPlots* in the classroom?" (N=61) | Classroom (n=10) | Novelty (n=6) | "…We did not have oral lessons, but practical lessons." |
| | | Groups (n=4) | "The advantages were because we interact more with our colleagues…" |
| | Technology (n=44) | Experience (n=16) | "*TinkerPlots* is a practical, easy way to study mathematics" |
| | | Organization (n=1) | "… [the software] have all the contents we have learned and because it is easy to access everything." |
| | | Practical (n=10) | "…We were able to represent the data in any graph quickly." |
| | | Measures (n=17) | "…We learned more about graphs, mean and median." |
| | Learning (n=55) | Understanding (n=16) | "…I started to improve my learning with graphs." |
| | | Knowledge (n=11) | "…We have learned how to perform graphs in different ways." |
| | | Easiness (n=20) | "…The software facilitated tasks resolution." |
| | | Motivation (n=8) | "*TinkerPlots* made statistical learning more interesting and fun." |


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|---|---|---|---|
| 3. "What have you enjoyed the most when working with *TinkerPlots*?" (N=61) | Classroom (n=4) | Novelty (n=4)<br>Groups (n=0) | "I enjoyed everything because for me it was a new and catchy experience." |
| | Technology (n=96) | Experience (n=19)<br>Organization (n=3)<br>Practical (n=35)<br>Measures (n=39) | "…Work mathematics in computer, since is something new as we work more with paper."<br>"What I enjoyed the most was to see how the balls organized."<br>"*TinkerPlots* just give us the results we wanted."<br>"What I enjoyed the most was to work with the mean and median." |
| | Learning (n=9) | Understanding (n=2)<br>Knowledge (n=1)<br>Easiness (n=3)<br>Motivation (n=3) | "…With the *TinkerPlots* was much easier to understand what we were called to perform."<br>"What I enjoyed the most was to discover the boxplot."<br>"I liked a lot to work with *TinkerPlots* because it was much easier to have computations done."<br>"…It is a good way for us to have fun while we perform mathematical exercises." |
| 4. "Did the group work help you to complete the tasks? Explain." (N=56) | Classroom (n=52) | Novelty (n=0)<br>Groups (n=52) | "Yes, because we were a group, we were more to discuss ideas and opinions"; "Yes, because my group could know things that I did not"; "Yes, because as a team we can accomplish things that we are individually not able to"; "It helped a lot, if I did not know things I asked my colleague and she helped me, and I helped her"; "Yes, because alone I perhaps would not be able to do even half of what I have done". |
| | Technology (n=0) | Experience (n=0)<br>Organization (n=0)<br>Practical (n=0)<br>Measures (n=0) | |
| | Learning (n=54) | Understanding (n=30)<br>Knowledge (n=6)<br>Easiness (n=15)<br>Motivation (n=3) | "Yes, since we are more [people] thinking. We could think more and better organize ideas."<br>"Yes, because we were able to learn with our peers what we did not know."<br>"Yes, because two heads think better than one, therefore it was much easier to perform de tasks."<br>"…It helped a lot to turn lessons funnier." |

***Table 2*. Classification of the Students´ Answer to the Four Questions Posed in the Negative Form, by Categories and Subcategories**

| Question | Category | Subcategory | Examples |
|---|---|---|---|
| 5. "In your opinion, did the use of *TinkerPlots* to complete the tasks facilitate your statistical learning? If not, explain why." (N=12) | Technology (n=3) | Manipulation (n=3) | "It did not facilitate since there were options difficult to find." |
| | Learning (n=3) | Interest (n=1)<br>Knowledge (n=2) | "No, I was carefree about the work to do."<br>"No, because I had no doubts in statistics." |
| 6. "Which were the disadvantages of using *TinkerPlots* in the classroom?" (N=41) | Technology (n=38) | Manipulation (n=12)<br>Instrumentality (n=3)<br>No disadvantages (n=23) | "…We shall need more lessons [using *TinkerPlots*] to learn to work on it…"<br>"The disadvantage was that we did not prepare ourselves for the final exam."<br>"I have nothing to say about the disadvantages because there were none." |
| | Classroom (n=3) | Data collection (n=1)<br>Environment (n=2) | "The disadvantages were the manual data saving."<br>"There was too much noise." |
| 7. "What have you enjoyed less in working with *TinkerPlots*?" (N=37) | Technology (n=29) | Manipulation (n=3)<br>Measures (n=17)<br>Limitations (n=1)<br>No disadvantages (n=8) | "I had much difficulty working with the software at the beginning."<br>"I did not like how we have to see the median."<br>"What I liked less was the fact that [*TinkerPlots*] did not have more things…"<br>"There was nothing that I have disliked." |
| | Classroom (n=8) | Data collection (n=8) | "What I enjoyed less was perhaps the need to record the files all times." |
| 8. "Did the group work not help you to complete the tasks? Explain." (N=10) | Groups (n=10) | Relationship (n=4)<br>Work (n=4)<br>Focus (n=2) | "……I like to work with people that I trust more and to whom I have a better relation".<br>"My peer merely writes on the computer. Unfortunately, I had to do by myself the remaining [work]."<br>"…In the first task we start talking a lot and we did not finish the task." |

The analysis to the question 1 (N= 46) shows that students value very positively the use of ICT for solving the tasks in these lessons (*Technology;* n=45). The possibility to use *TinkerPlots* to explore specific statistical *Measures* (n=19) was the aspect they mentioned the most, followed by the chance to get to know *TinkerPlots* software (*Experience;* n=11). They also valued the *Practical* (n=8) nature of ICT and recognized *TinkerPlots'* facility to organize data and statistical information, in general (*Organization;* n=7). There is also a significant number of references that express students' recognition of the impact of *TinkerPlots* in their learning processes in statistics (*Learning;* n=44), highlighting how this experience helped them to understand statistical concepts they have previously learned but were not fully understood, and to interpret what was demanded by the questions they were called to answer (*Understanding;* n=18). Some students also perceived that this experience enable them to enhance their knowledge of statistics (*Knowledge;* n=12).

Regarding question 2, almost all students (N=61) identified the advantages of using the computer in these lessons. Most of the references they have made focus on the use of ICT as being valuable and helpful for their learning in statistics (*Learning;* n=55). *Easiness* was the aspect in that category that students mentioned the most (n=20) followed by *Understanding* (n=16). In terms of mathematical resilience it is important to notice that if we take together the subcategories *Understanding* and *Knowledge* (n=27) these encompass the majority of students' references concerning the advantages of using the software in the classroom within the category of *Learning*. With respect specifically to the inclusion of ICT in these lessons (*Technology;* n=44), students highlighted its advantages regarding the possibility of exploring different measures of central tendency, such as boxplots, mean and median (*Measures;* n=17). Students also perceived this as an unusual and non-conventional *Experience* (n=16) which enabled them to learn statistics in a different learning setting.

In what concerns question 3 (N=61), students clearly highlighted their use of the software (*Technology;* n=96), as the most enjoyable aspect of the experience. Students pointed out the measures of central tendency as the aspect which they enjoyed the most to work with (*Measure;* n=39), and secondly they express their preference for the characteristics of the software which enables them to perform more in less time, and put into practice their theoretical knowledge (*Practical;* n=35).

As regard to question 4 (N=54), students highly recognized a positive impact of working in groups in their *Learning* process (n=54). *Understanding* (n=30) was the aspect students mentioned the most, as they perceived that they benefit from each other ideas to go deeper in and enhance their comprehension of statistical concepts. Students also highlighted the *Classroom* (n=52) environment change, specifically regarding the possibility to work with their peers, and valued sharing each other ideas (*Groups;* n=52). Students did not mention technology in relation with group work.

Concerning the questions posed in a negative form, when answering question 5 there are some students (N=12) who do not consider that the use of *TinkerPlots* facilitated their learning in statistics. A residual number of students perceived *TinkerPlots* (*Technology;* n=3) as difficult to manage (*Manipulation;* n=3) and suggested that it was an obstacle to their performance.

As regards to question 6 (N=41), within the category *Technology* (n=38) the majority of the students express the absence of disadvantages in using ICT in these lessons (*No disadvantages;* n=23), while others pointed out the difficulty they faced when using *TinkerPlots*, claiming the need to get deeper familiarized with it (*Manipulation;* n=12).

In question 7 (N=37), students commented specific aspects of the software that seemed to have been less enjoyable for them (*Technology;* n=29) especially with reference to particular statistical measures or procedures (*Measures;* n=17), although others did not identify any aspect less enjoyable regarding its use (*No disadvantages;* n=8).

Finally, regarding question 8 (N=10), a small number of students perceived the experience of working with their peers as uncomfortable (*Groups;* n=10), mainly due to relational affinity reasons (*Relationship;* n=4) or a lack of sense of cooperative *Work* (n=4).

## Discussion

The results described above illustrate important aspects in connection with the notion of mathematical resilience that has been adopted in this study. Students reported that these experiences enable them to learn new content and to have a deeper understanding of previous learned contents, which have the underlying idea that they believe they can enhance their learning process and become better in mathematics. Students also highlighted the importance of their peers in this experience, recognizing the mutual help and the team spirit as essential to their successful task completion, which is an important element when characterizing mathematical resilience (Lee & Johnston-Wilder, 2013). The importance of the team work perceived by students, as well as the mutual help they gave and receive from their peers, seems to be a source of perseverance behaviors for students, that make them proceed in the learning process, with the support of their colleagues, when facing difficulties in that process.

Despite these positive outcomes, it did not emerge from the students' answers their understanding regarding the instrumentality of mathematics content outside the classroom setting. As this premise was not intentionally asked to students, we could not assume that there is a lack of this understanding; in turn, since the tasks students enrolled in were based on SRLE principles, especially on the one concerning the use of real data, we may assume that students are aware of the relation between the activity they have developed and the outside academic context. As a matter of fact, the teachers of these classes stress the importance for students of working with real data in these tasks (Oliveira & Henriques, 2014).

Results presented above illustrate important aspects of the students' voice about using ICT in the mathematics classroom. One of the most noteworthy is how students perceived ICT as enabling them to perform the tasks easily and faster. Accordingly to their feedback, students were able to access in a simple way to a huge amount of data and better organize them and make diverse types of graphical representations and computations for specific statistical measures. Consequently, we could assume that they perceived the learning processes created by the inclusion of ICT in their classrooms as being easier to them, meaning that they felt they could perform better and enhance their learning in a SRLE environment. At the same time, students reported this as a different and enjoyable experience, which in turn enlarged their motivation to enroll the proposed classroom activities.

Although the majority of students pointed to perceived positive outcomes from this experience, some reported feelings of distress whilst others indifference. In one hand, students' lack of technical skills to master *TinkerPlots* tools inhibited their active involvement in the tasks and generated negative feelings about their abilities to enhance learning. On the other hand, some students did not perceive the tasks as part of their learning mathematical content and did not undertake this experience as mathematics lessons. Despite the residual number of students that fall into these two perceptions, these findings suggest the importance to ensure that all students have the needed skills to master specific ICT tools in classroom, giving them a reasonable adjustment period; we could also assume that for some students, teachers could have not given the support they needed to enroll the tasks in a safe and effective way. These findings are consistent with previous research results regarding students' voice about ICT experiences (e.g., Deaney et al., 2003) and corroborate the idea that ICT could improve educational outcomes (Livingstone, 2012).

## Conclusions

The main goal of this research was to study how students attending schools in the sub-urban area of the Portuguese capital are able to recognize and exhibit mathematical resilience characteristics after solving tasks using *TinkerPlots* software in the theme of statistics. Although we cannot assert that using ICT in mathematics classroom develops students' mathematical resilience, we may claim these Portuguese students exhibited some characteristics the specialized literature describes as typical for mathematically resilient students (Lee & Johnston-Wilder, 2013). By using the appropriate technology to assist the teaching-learning process and with the support of their peers and teacher, students were able to solve tasks with complex learning objectives.

Since mathematics is perceived by students as one of the most demanding and difficult school subjects, it becomes imperative to develop strategies in schools whereby they may feel confident to enhance their mathematical learning and academic performance. Teachers and students are the main protagonists of the teaching-learning process and for that reason it is important to raise teachers' awareness of their role in promoting mathematical resilience. To develop and promote mathematical resilience in an effective and thoughtful way it becomes necessary that teachers understand its importance in academic achievement, specifically in mathematics, and are able to identify opportunities to work on resilience with their students in their classrooms' daily life context. It is priority that teachers intentionally and regularly promote and help students develop resilient behavior that enables them to understand the difficulties they are facing and how they can overcome them; for that, students need to feel they can have the support they need and that the effort they put in the mathematical activity is well worth it.

As students are the main actors of the learning process, in this study we intended to enable them to express their point of view regarding the issues that are perceived by them as important to their learning commitment and enhancement. When allowing their students to express themselves, teachers will gain new insights about how students could enhance their learning and commitment with school matters. This is particularly significant with students with lower outcomes as it is to give them the opportunity and encouragement to think about their own learning process (Flutter, 2007). This new approach is opposite to the conventional restrictive practices (Nardi & Steward, 2003) currently taking place in the classroom, in which teacher has a full-time main role showing the concepts to be learnt, followed by students solving exercises. New approaches, such as the SRLE described in this paper, requires a mentalities shift for which all school community should be sensitized (Yeager & Dweck, 2012).

Psychologists in schools could contribute to an awareness of teachers and parents to the importance of promoting and helping students to develop resilient behaviors in mathematics and in other curricular issues, as well as outside school subjects. As Yeager and Dweck stress (2012), "When we emphasize people's potential to change, we prepare our students to face life's challenges resiliently" (p. 312).

*Limitations*

Although this study allows us to start conceiving how the use of ICT in the classrooms, under certain circumstances, may promote students' mathematical resilience, there are also some limitations that come out. Firstly, as this study is part of a broader research project aiming to develop students' statistical literacy, the tasks enrolled in this study were focused on the statistical domain and not on mathematics in general. Therefore as the software is targeted only for the theme of statistics, more studies are needed with other software targeting different contents in mathematics. We also identify limitations in the instrument used for data collecting in order to fully grasp all elements to be considered in mathematical resilience. In a further study, this method could also be complemented with different data from the classroom. Finally, to enhance students' mathematical resilience significantly it would be necessary to extend the experience for a longer period of time.

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