Real Contexts in Problem-Posing: An Exploratory Study of Students' Creativity

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Abstract

The aim of this paper is to start investigating how different real contexts could influence students' creativity in semi-structured problem-posing activities. In order to pursue this goal, an exploratory study was implemented in a lower secondary school class in which two kinds of real contexts had been considered: a *real-mathematical* context and a *real-life* context. Results from the study indicate that there was not a significant difference in students' creativity between the use of a real-mathematical and a real-life context as starting situations for semi-structured problem-posing activities. However, a fundamental factor that influenced students' problem-posing performances was the meaningfulness given by students to the context. When the context was not experientially meaningful for a student, she/he tried to associate a new meaning to the context, using some elements from it to re-create a new realistic context in which setting her/his problems. In conclusion, to best support students in posing their problems, the significance of the context appears to be an important factor, in order to increase the opportunities in making connections between mathematics in and outside the classroom, and in helping students in giving sense to their mathematical activity.

Introduction

In order to help students to cope with social environments and demands (Singer, Ellerton, & Cai, 2015), the types of problem-solving experiences they are engaged in at school need to be rethought (Albarracìn & Gorgoriò, 2019; Russo, 2019; Bonotto, 2013). Realistic and less stereotyped problems that take into consideration the experiential world of students must be integrated into school practice, in order to create a bridge between mathematics classroom activities and everyday-life experiences. Allowing students to write their own mathematical problems may help them to make connections between mathematics in the classroom and their real life (Kopparla et al., 2019). In this direction, problem-posing should represent a valuable strategy to support students with their mathematical activities filling the gap between in- and out-of-school mathematical competencies and experiences, as requested in many curricular and pedagogical innovations in mathematics education (National Council of Teachers of Mathematics [NCTM], 2000).

Although mathematical problem-posing has great importance in mathematics education, it has received little attention by students, teachers and researchers (Passarella, 2021b; Lee, 2020; Van Harpen & Sriraman, 2013; Silver, 2013). Further research is needed (Ellerton, Singer, & Cai, 2015), particularly on: developing problem-posing skills for teachers' education; analysing connections between problem-posing and creativity; supporting students' learning through problem-posing.

This paper adds to the research on problem-posing by investigating how different real contexts for *semi-structured* problem-posing activities (Stoyanova & Ellerton, 1996) could influence students' responses in terms of creativity.

Theoretical Background

Problem-posing

In this paper, problem-posing is considered to be the process by which students construct personal interpretations of concrete situations and formulate them as meaningful mathematical problems (Stoyanova & Ellerton, 1996). To define such situations, two main directions of task design for problem-posing emerged in the literature. The first involves specific mathematical or daily-life situations (Chen, Van Dooren, Chen, & Verschaffel, 2011). The second refers specific principles for participants to follow when posing mathematical problems. Concerning this second trend, Stoyanova and Ellerton (1996) identified three categories of problem-posing situations: *free situations*, in which students are asked to pose problems with no restrictions or further information; *semi-structured situations*, in which students are provided with an open situation and are invited to pose problems based on that given situation; *structured situations*, in which students can only vary some attributes or conditions of a specific given problem.

Various aspects of problem-posing have been studied in the literature (Lee, 2020), such as examining thinking processes related to problem-posing (Brown & Walter, 1990; Christou et al., 2005), or including problem-posing in mathematics activities. In particular, several studies focused on the relationship between problem-posing and problem-solving (Silver, 1994), showing that students engaged in problem-posing activities also improved their problem-solving abilities (Van Harpen & Presmeg, 2013; Cai & Hwang, 2002). Problem-posing affords students the unique opportunity to improve their problem-solving skills while developing their academic skills to encounter and solve problems in mathematics and beyond (Kopparla et al., 2019).

Creativity in problem-posing

Another aspect of problem-posing that has been investigated in the literature is its relationship with creativity. Creativity started receiving attention when Guilford (1959) proposed *fluency, flexibility* and *originality* as characterizing aspects of creativity: fluency in thinking refers to the quantity of output; flexibility in thinking refers to a change of some kind (meaning, interpretation, use of something, strategy, etc.); originality in thinking means the production of unusual, remote or clever responses. The previous categories had been used in tests by Torrance (1966) and in other studies such as those by Kontorovich, Koichu, Leikin, and Berman (2011), and Bonotto (2013).

More recently, Xie and Masingila (2017) proposed a scoring rubric to assess prospective teachers' problem-posing performance. In particular, in relation to a given problem, they analysed teachers' posed problems in terms of creativity as shown in Table 1.

Table 1. Rubric proposed by Xie and Masingila (2017)

	3 points	Completely different problem
Creativity of the posed problem	2 points	Somewhat different problem
	1 point	Comparable problem

Results from several studies that used problem-posing to promote and assess creativity (Xie & Masingila 2017; Bonotto 2013; Leung & Silver 1997), showed that an inquiry-oriented mathematics instruction, including problem-posing activities, could assist students to develop more creative approaches to mathematics. Specifically, when students are engaged in semi-

structured (Stoyanova & Ellerton 1996) problem-posing activities, a creative process can be encouraged by the use of cultural artefacts (Bonotto & Dal Santo 2015).

Despite the significance of problem-posing activities as opportunities for measuring students' creativity, there is a need for additional research in understanding how problem-posing could actually enhance students' creativity. Specifically, which situations best support and foster students' creativity during problem-posing activities? As suggested by Cai et al. (2015), it is mandatory to develop and validate suitable problem-posing instruments, understanding which kinds of problem-posing tasks best reveal students' creativity and their mathematical understandings. This paper focuses on the role of different real situations in semi-structured problem-posing activities, in order to start investigating their influence in students' creativity. Since the emphasis of this work is only on semi-structured situations, i.e. activities in which students are invited to generate problems from a given context, the choice of such context is central. In the next section two different perspectives are presented, in order to define which kinds of *real contexts* have been considered in this research.
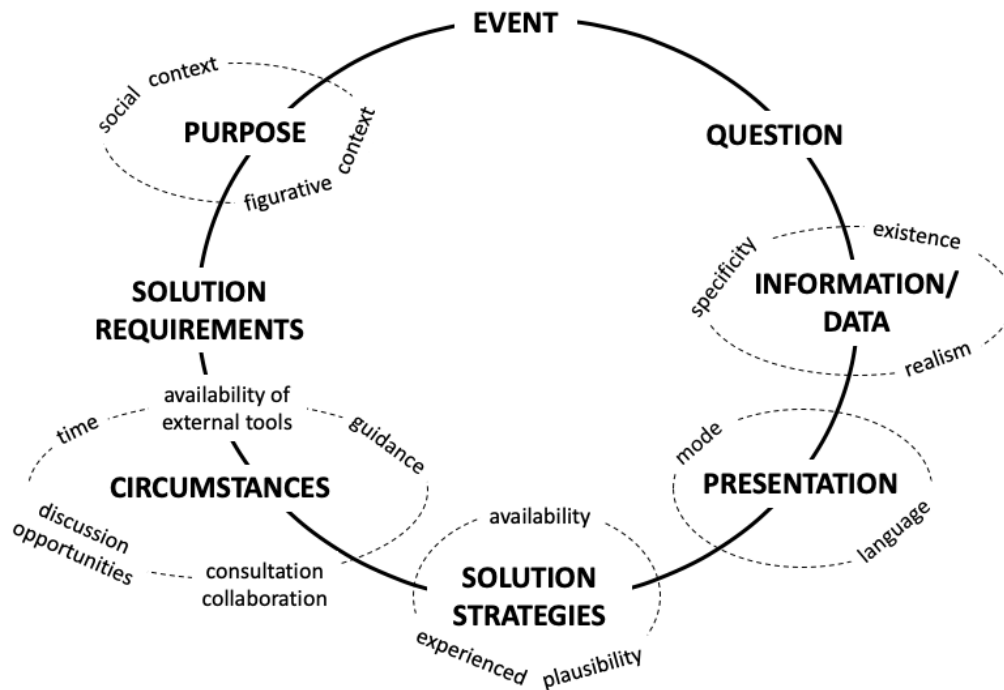
Real contexts
Results from several studies indicated the importance of contexts in supporting students in making sense of problem situations (Van Den Heuvel Panhuizen, 2005; Passarella, 2021a). Semi-structured problem-posing situations, permitting students to generate their own problems, may help students in this process of sense-making. As a consequence, it is fundamental to start characterizing which features a context should have to best support students in posing their mathematical problems. In this paper contexts refer to the characteristics of a task presented to students, concerning the situation in which the task is situated, or simply to the words and/or pictures present in the task to help students in its understanding (Borasi, 1986). Specifically, since in this research problem-posing is considered a means to fill the gap between in- and out-of-school mathematical competencies (Passarella, 2021b), a connotation for contexts for problem-posing activities is that they should be real. But what is a *real context*? Two approaches from the literature that should help in answering this question are presented, in order to define which sorts of real contexts will be considered in the rest of the paper. The first approach refers to *realistic* and *rich* contexts in the perspective of Realistic Mathematics Education (RME), while the second one is a framework developed by Palm (2006) concerning the concordance between mathematical school tasks and the corresponding out-of-school situations.

Rich and realistic contexts
At the core of RME is the fact that mathematics education should take its point of departure primarily in mathematics as an activity, and not in mathematics as a ready-made-system (Freudenthal, 1991). Learning is a constructed understanding through a continuous interaction between teacher and students, that can be synthetized, using Freudenthal's words, in teaching and learning as "*guided reinvention*". Anchoring points for the reinvention of mathematics are offered by *rich* and *realistic* contexts. Realistic contexts are contexts that represent problem situations experientially real to students (Gravemeijer & Doorman, 1999). Problems should come from the real-world, but also from a fantasy world or from the mathematics itself, until they are experientially real for the student (Van den Heuvel-Panhuizen & Drijvers, 2014). Besides to this *realistic* connotation, a context must also be *rich* (Freudenthal, 1991). A rich context is a context that promotes a structuring process as a means of organizing phenomena, physical and mathematical, and even mathematics as a whole, i.e. contexts that give more opportunities in the mathematization process (Treffers, 1987).

Palm's framework

The second task framework presented by Palm (2006), was developed to depict the aspects of real-life situations that should be considered important in simulations (Figure 1).

EVENT

PURPOSE — social context — figurative context

QUESTION

INFORMATION/DATA — specificity — existence — realism

SOLUTION REQUIREMENTS

availability of external tools — guidance

PRESENTATION — mode — language

CIRCUMSTANCES — time

discussion opportunities — consultation collaboration

availability

SOLUTION STRATEGIES — experienced plausibility

Figure 1. Palm's (2006) framework

A complete description of these aspects can be found in Palm (2006). In particular, the author gives some suggestions concerning what to take into account to have a real mathematical task, in the sense of making it as close as possible to a corresponding real-life situation. Consequently, in this perspective a real context can be described by three main concepts: *feasibility, availability* and *appropriateness*. Feasibility refers to the fact that the context, and eventually the problem formulated from it, should actually occur in real-life. Availability means that students should have at their disposal information and strategies to solve the problem sufficiently close to real-life data. Appropriateness concerns the fact that the purpose must be clear to students, and consequently students are able to discern which solutions could be considered as appropriate in relation to the context of the problem. In this perspective, real contexts are similar to the notion of *artefact* used in Bonotto (2013). Indeed, artefacts create an interaction between school mathematics and extra school experiences, by bringing students' everyday-life experiences and informal reasoning into play.

Real-mathematical contexts and real-life contexts

Based on the dichotomy between the two concepts *realistic-rich* vs *feasibility*, in the rest of the paper two types of real contexts will be considered: *real-mathematical* contexts and *real-life* contexts (Figure 2). A real-mathematical context is defined as a context that comes from the world of mathematics and that is both rich and realistic, in line with the perspective of RME. A real-life context, instead, is a real context in line with Palm's framework, i.e. it is feasible, available and appropriate.
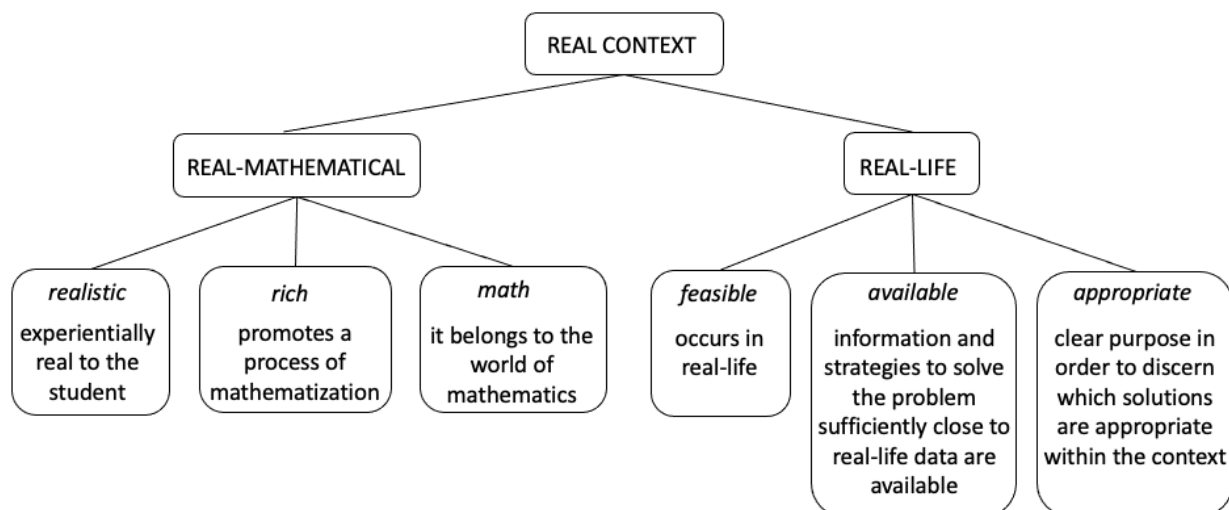
Figure 2. Real contexts considered in this study

Research Question

Despite the importance of problem-posing activities in mathematics classrooms, we have outlined how additional research in understanding how problem-posing could actually enhance students' creativity is needed, investigating which situations and tasks could best support and foster students' creativity during problem-posing activities (Cai et al., 2015). The aim of this study is to start investigating how different real contexts may influence students' creativity in problem-posing. Specifically, the research question that this study investigates is: how do different real contexts influence students' creativity in problem-posing?

In order to answer this research question, an exploratory study was implemented, in which two kinds of real contexts were considered: a real-mathematical context and a real-life context, as defined in the previous section. Students' problem-posing performances were analysed in terms of creativity and compared between contexts, in order to explore which kind of context, real-mathematical and real-life, would best support students' creativity in problem-posing.

The Study

Participants and procedure

To answer the research question, an exploratory study was conducted with a lower secondary school class. The participants were twenty-two students in grade six (age 12). The class had no previously engaged in a problem-posing activity. At the time of the intervention, students were working on fractions. The official mathematics teacher, who was used to teaching in a traditional way, worked with students on comparisons between fractions, basic operations with fractions, fractions in the number line, and word problems with fractions. To have an overview of the students' level on this topic, a test was administered before the implementation of the problem-posing activity. The test consisted of six questions on concepts already covered in previous mathematics lessons, specifically: three questions on performing operations between fractions; two questions involving fractions in the number line; a word problem. Even when results from the test showed that students had difficulties in solving word-problems, a good score was obtained concerning questions with the number line, a fact that was used in the design of the following problem-posing activities.

As the aim of this research was to investigate the impact of different real contexts on students' creativity in problem-posing, the study consisted of two different problem-posing sessions. Both problem-posing sessions, each lasting about 40 minutes, consisted of individual problem-posing activities in which students had to create at least three problems dealing with fractions starting from a given context. The contexts used for the two problem-posing sessions included a real-mathematical context in the first session, and a real-life context in the second session. The context for the first problem-posing session consisted of a number line with some rational numbers, while the context for the second session consisted of an advertising leaflet containing discounts for mobile phones (Figure 3). The number line context comes from the mathematical world, but at the same time was considered realistic, as it is experientially significant for students who previously worked on it with their teacher and showed good results in the initial test, and rich in terms of the perspective of RME. The second context is more in line with Palm's framework, as it consists of a real leaflet, representing an event that can occur in real life. The task was administered to students in written form. For each problem-posing session, students were given a sheet of paper with the picture of the corresponding context (number line for the first session and leaflet for the second session) and the request was to pose at least three problems from the given context dealing with fractions. The task was first read with the mathematics teacher to ensure that the request was clear to all students. In order to not influence students in posing their problems, no previous examples were given to them.
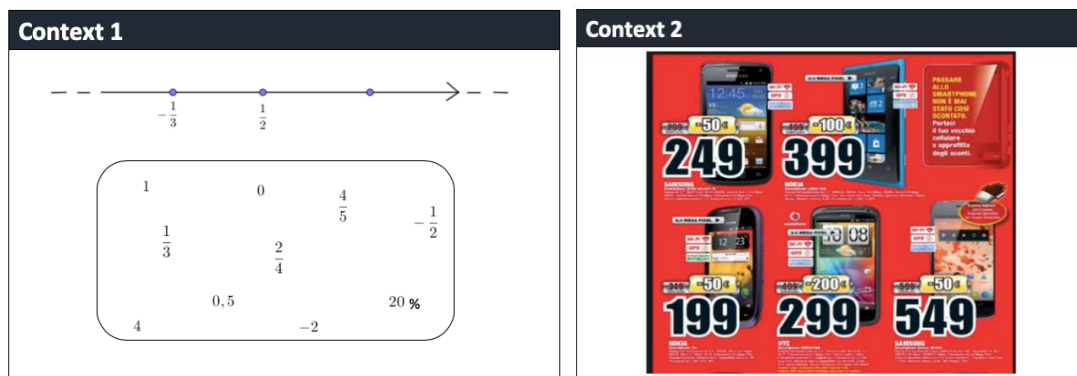

Figure 3. Contexts for the problem-posing sessions

Data coding
Data from the study included the problems posed by students during the two problem-posing sessions. The data coding followed two main steps: the first involving the quantity and quality of the problems posed by students; the second concerning students' creativity. A summary of the data coding scheme used in this study is provided in Figure 4.

The first phase of data coding involved a variation of the model proposed by Leung and Silver (1997). Students' problem-posing responses were first categorized as *problems* or *statements*. Then, *problems* were classified as *mathematical* or *not-mathematical problems*. Each *mathematical problem* was then analysed in two directions. First, a mathematical problem was classified as *context related*, i.e. set in its starting context (the number line for the first session and the leaflet for the second session), or as *not context related*. Second, *mathematical problems* were divided between *solvable* and *not solvable*. Problems were considered to be *not solvable* if they lacked sufficient information or if they posed a goal that was incompatible with the given information.
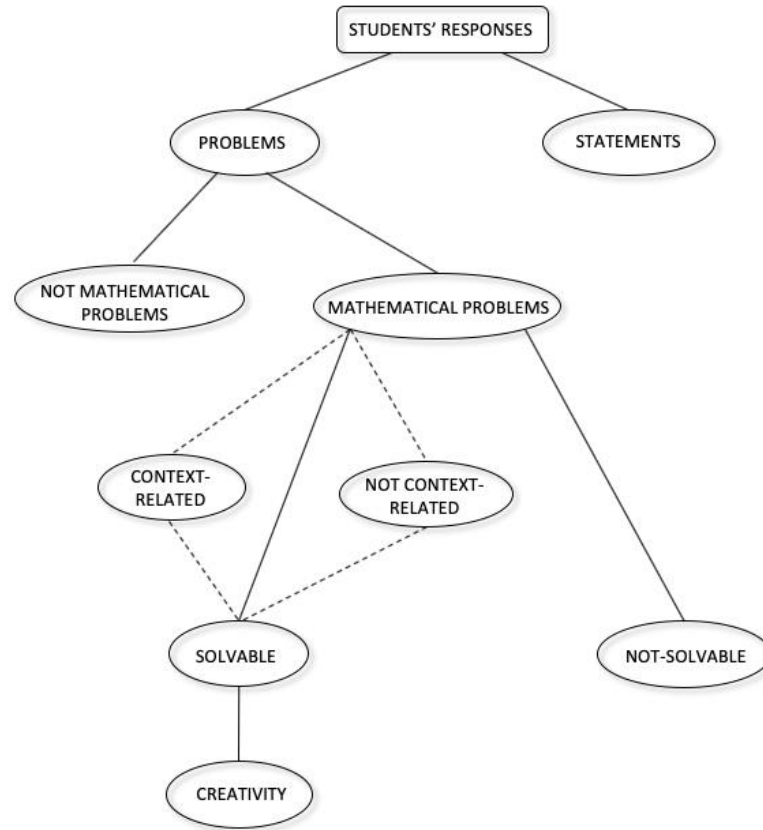
Figure 4. Data coding scheme

The second phase of data coding involved examining the creativity of the problems that were classified as *solvable*. In order to explore which context best supported students' creativity, for each problem-posing session this data coding phase involved the following steps (Figure 5): (i) calculation of the level of creativity of each student and (ii) calculation of the distributions of students in respect to their level of creativity. In the end, results from the first and the second problem-posing sessions were compared. In order to ensure inter-rater reliability of the scoring, the data analysis was performed separately by the author and a colleague and then Cohen's Kappa were calculated.
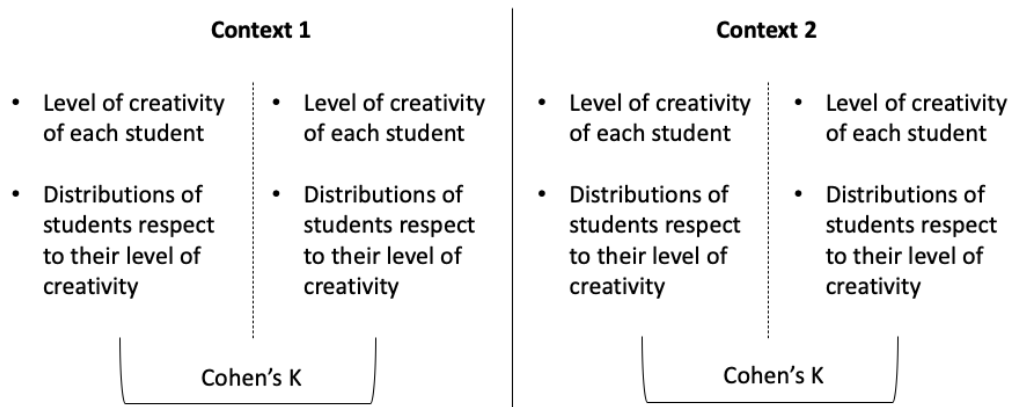
Figure 5. Coding steps

In order to assign each student response a level of creativity, an analytic scheme was developed. The scheme is rooted in the rubric proposed by Xie and Masingila (2017). Although this rubric was developed by the authors to assess the creativity of mathematics teachers, it was considered a suitable starting point for assessing the creativity of students as well, in terms of comparability and differentiation between problems posed by students from a semi-structured situation. It is highlighted that the level of creativity defined below, reflects only the flexibility component in Guilford's (1959) model. Let P_i^n be the i-th problem posed by the n-th student, so in the case of three problems $i = 1, 2, 3$; $n > 0$. For every n, consider the first posed problem, namely P_1^n, and start comparing it with the second posed problem P_2^n:

$$(P_2^n, P_1^n) = \begin{cases} 0, & \text{if } P_2^n \text{ and } P_1^n \text{ are comparable} \\ +1, & \text{if } P_2^n \text{ and } P_1^n \text{ are somewhat different} \\ +2, & \text{if } P_2^n \text{ and } P_1^n \text{ are completely different} \end{cases} \tag{i}$$

Then consider the third posed problem and compare it with both the second and the first one:

$$(P_3^n, P_2^n) = \begin{cases} 0, & \text{if } P_3^n \text{ and } P_2^n \text{ are comparable} \\ +1, & \text{if } P_3^n \text{ and } P_2^n \text{ are somewhat different} \\ +2, & \text{if } P_3^n \text{ and } P_2^n \text{ are completely different} \end{cases} \tag{ii}$$

$$(P_3^n, P_1^n) = \begin{cases} -2, & \text{if } P_3^n \text{ and } P_1^n \text{ are comparable} \\ -1, & \text{if } P_3^n \text{ and } P_1^n \text{ are somewhat different} \\ 0, & \text{if } P_3^n \text{ and } P_1^n \text{ are completely different} \end{cases} \tag{iii}$$

In conclusion, calculate the sum $c := (P_2^n, P_1^n) + (P_3^n, P_2^n) + (P_3^n, P_1^n) \in \{-2, -1, 0, 1, 2, 3, 4\}$. In the end, to each student is associated a level of creativity in accordance with Table 2.

Table 2. Student's level of creativity associated to the value of c

c	level of creativity
≤ 0	Low (L)
1 or 2	Medium (M)
> 2	High (H)

In the case where one student poses only one problem ($d=1$), c is defined as $c = 0$. If a student poses only two problems, c is calculated according to (i).

The scheme can easily be extended to activities in which students pose a number of problems greater than three. In this case, the level of creativity of each student is associated to the quantity $c := \sum_{j=2}^{d}\left(\sum_{k=1}^{j-1}(P_j^n, P_k^n)\right)$, with

$$(P_j^n, P_k^n) \in \begin{cases} \{0, +1, +2\}, & j - k = 1 \\ \{-2, -1, 0\}, & j - k > 1 \end{cases}$$

according to (i) and (iii), where d is the maximal number of problems posed by a single student, and P_i^n is the i-th problem posed by the n-th student, $i = 1, \ldots, d$. It can be observed that in general there are $d - 1$ pairs (P_j^n, P_k^n) with $j - k = 1$, and $(\sum_{m=1}^{d-2} m)$ pairs (P_j^n, P_k^n) with $i - j > 1$. As a consequence, the quantity c lives in $B := \{z \in \mathbb{Z} \mid h < z < l\}$, where $h = -2 \cdot \sum_{m=1}^{d-2} m$, and $l = 2 \cdot (d - 1)$.

Results

Problem-posing responses
Students' responses were firstly analysed using the data coding scheme reported in Figure 4. Results, split between the two contexts, are reported in Table 3. All of the students' responses were classified as *problems*, so no *statement* occurred. Students posed a total of 122 problems, of which 95% were *mathematical problems*. The number of *mathematical problems* was comparable between the two contexts, respectively 97% of the posed problems for the number line and 92% of the posed problems for the leaflet. The main (also statistical) difference between the two contexts deals with *context/not context related problems* (p<0.001; V=0.81). In the case of the number line, 92% of the *mathematical problems* were problems that did not refer to the number line. Instead, for the leaflet there was an opposite outcome, where 100% of the *mathematical problems* were *context related*, meaning they all referred to the leaflet itself. In Table 4 some examples of *context/not context related problems* are reported. In conclusion, no significant difference occurred between the two contexts in terms of *solvable* and *not solvable problems* (p<0.05; V=0.19). In fact, for the number line, 98% of *mathematical problems* were *solvable*, and for the leaflet, 90% of the *mathematical problems* were *solvable*.

Table 3. Students' responses

		Math. Problems	Not Math Problems		Context Related	Not Context Related	Solvable	Not Solvable
Context 1 (number line)	count	64	2	count	5	59	63	1
	% within problem	97	3	% within math problem	8	92	98	2
Context 2 (leaflet)	count	58	5	count	58	0	52	6
	% within problem	92	8	% within math problem	100	0	90	10
Total	count	122	7	count	57	65	115	7
	% within problem	95	5	% within math problem	47	53	94	6
					(p<0.001; V=0.81)		(p<0.05; V=0.19)	

Table 4. Examples of *context* and *not context related* problems

| Context 1 (number line) | context related | Marco is doing his math homework, he has to place the following numbers on the number line: 4, 0, 2/4. Help Marco by finding their value and placing them on the number line |
	not context related	Luisa is reading a book of 350 pages. If she has already read the 4/5 of the book, how many pages will she have to read to finish it?
Context 2 (leaflet)	context related	A phone is sold in a shop for the price of 299 euros. It is discounted by 40% and Tommaso paid 1/4 of the cost. How much does he still have to pay by counting the discount and the advance payment?
	not context related	No problem was not context related

As already states, 92% of the *mathematical problems* posed by students in the first problem-posing session, i.e. starting from the real-mathematical context represented by the number line, were *not context related problems*. Indeed, the majority of students, when posing problems from this context, used only some numbers present in the given context to pose problems in different situations. Further examples of *not context related problems* from the first problem-posing session are reported in Table 5.

Table 5. Examples of *not context related* problems from the first context

| P.1 | Giada would like to buy a toy that costs 10 euros, but she has only the 4/5 of 10 euros. How much more money does she need to buy the toy? |
P.2	Luca is playing football. One side of the football field measures 25m, and the other its 4/5. Which is its measure?
P.3	Marco and Anna collected 40 shells on the beach. Anna collected 2/4 of those collected by Marco. How many shells did Marco collect?
P.4	Matilde has 30 euros and Gianna has 2/4 of 30 euros. How much money does Gianna have? Who has more money?
P.5	Luigi has 27 marbles. Luca has 1/3 of those who Luigi has. How many marbles does Luca have? Which is the total number of marbles?
P.6	Laura has 70 euros. Giovanni has the 2/4 of Anna's money who has the 4/5 of Laura's. How much money does Giovanni have? And Anna?
P.7	Sara has 125 euros. In a shop there is a bicycle that costs 135 euros, but it is discounted by 20%. Will Sara be able to buy that bicycle?
P.8	Marco has to cover 6 kilometers to go to school, and Giulia 1/3 of Marcos's. How many kilometers does Giulia have to cover to go to school?
P.9	Umberto buys a copybook that costs 20% more than the older one, that costs 1,99 euros. How much does the new copybook cost?
P.10	Anna is reading a book of 420 pages. She has already read the 4/5 of the total. How many pages has she already read? How many pages are left to finish the book?

Creativity

The second phase of the data analysis involved classifying students' creativity. For each problem-posing session, firstly, a level of creativity was calculated for every student, applying the coding scheme described in the 'Data coding' section to the problems that had previously been classified as *solvable*. An example of this process is given in Figure 7. Secondly, distributions of student responses in respect to their level of creativity were calculated. Results are reported in Table 6 and Figure 8. In order to ensure inter-rater reliability of the scoring, Cohen's kappa was calculated. For the first context k=0.84, and for the second one k=0.85, which show in both cases an almost perfect agreement between the analyses performed by the two researchers.
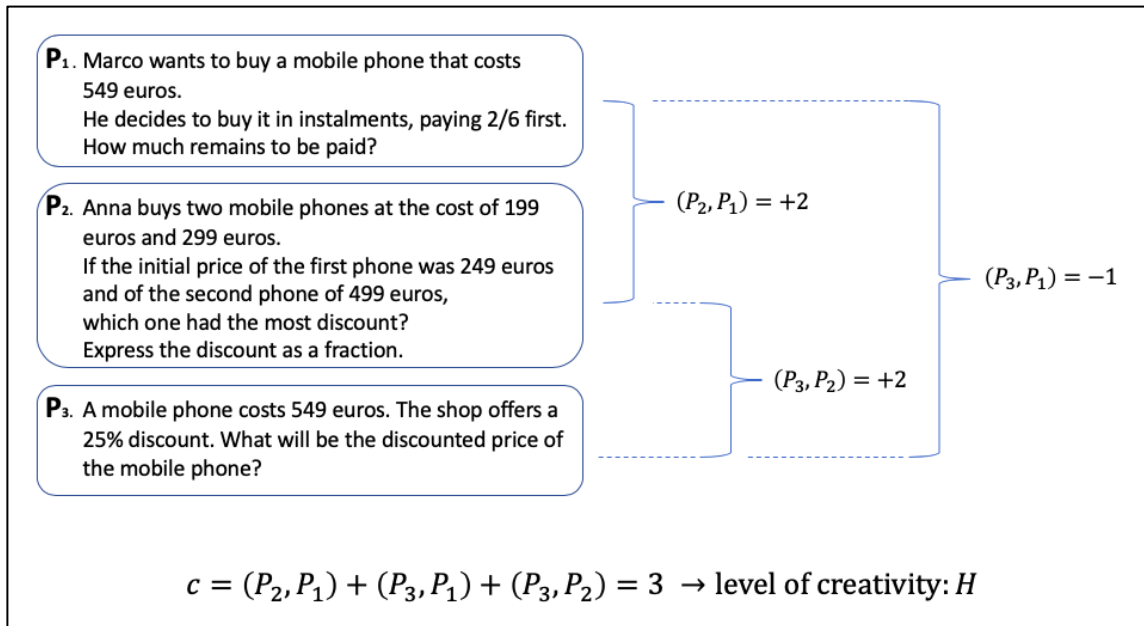
Figure 7. Level of creativity of a student

Table 6. Students' level of creativity distributions

	Context 1 (number line)				Context 2 (leaflet)			
	Count	%	Mean	SD	Count	%	Mean	SD
Low creativity level	10	45	- 0,6	1,0	10	45	-0,8	1,0
Medium creativity level	11	50	1,3	0,5	10	45	1,2	0,4
High creativity level	1	5	3	0,0	2	10	3,5	0,7
Total	22	100	0,5	1,5	22	100	0,5	1,3
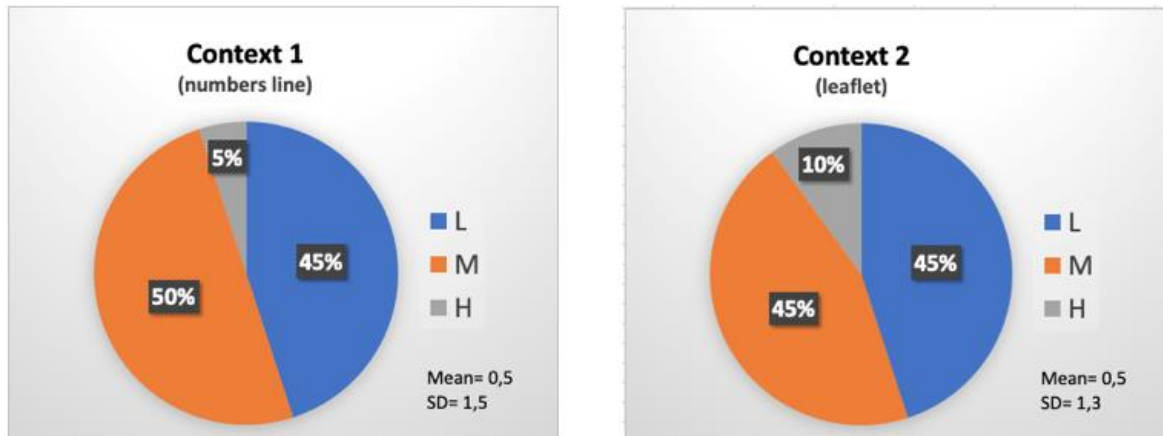
Figure 8. Students' level of creativity

Regarding the number line, 45% of students had a low level of creativity, 50% of students a medium level of creativity and 5% of students a high level of creativity. Regarding the leaflet, 45% of students had a low level of creativity, 45% of students a medium level of creativity and 10% of students a high level of creativity. As clearly shown in Figure 8, students' problem-posing responses in terms of level of creativity are comparable. This is supported also by a Wilcoxon test, that indicated no significant difference in terms of level of creativity in student problems between the two contexts (z=-0.1; p=0.9).

Discussion and conclusions

In this research we explored how different real contexts could influence students' creativity in problem-posing. In order to answer the research question, an exploratory study was conducted with a lower secondary school class, consisting of two problem-posing sessions. Each problem-posing session was implemented as a semi-structured (Stoyanova & Ellerton, 1997) activity, in which students were asked to pose some problems from a given real context. In each problem-posing session, a specific type of context was considered: a number line, representing a *real-mathematical* context, and a mobile phones leaflet, representing a *real-life* context, for the first and the second session respectively.

The results of the study give an initial insight into how different real contexts might influence students' creativity in semi-structured problem-posing activities. The first part of the data analysis involved evaluation of differences and/or similarities between the two problem-posing sessions in terms of the quality of the posed problems. The only significant difference between the two problem-posing sessions was in terms of *context/not context* related problems (Table 3): 92% of *mathematical problems* posed starting from the number line were classified as *not context related*. This means that students actually did not consider the number line a meaningful context for setting their problems. The majority of students, instead, used the numbers given in this context (Figure 2) to pose problems that were not related to the number line context itself. As clearly shown in Table 5, these problems were instead related to students' real-world experience and posed similarly to word-problems they had found in their previous mathematical experience. As a consequence, despite the number line being used by the teacher in previous mathematics lessons and students having good results in solving exercises with it as shown in the initial test, it was not a significant context for students, possibly lacking in a real-life occurrence, and therefore not experientially meaningful for them. With the second context however, 90% of students' *mathematical problems* were *context related*. Students

recognised the leaflet as a familiar context that can occur in their real life. As a consequence, students were able to pose problems that were set in that context. It is also noted that the difference between the two contexts in terms of their possible real occurrence did not affect problems' solvability. The majority of students' *mathematical problems*, in fact, in both cases were characterised as *solvable* problems (98% for the number line and 90% for the leaflet).

The second part of the data analysis explored creativity. In both the problem-posing sessions, students' levels of creativity were approximately equally distributed between low and medium-high levels of creativity. Moreover, no significant difference was found between the use of the number line and the leaflet. As a consequence, based on the results of this study, it cannot be stated that a more meaningful context for students, such as the mobile phone leaflet, promoted increased students' creativity compared to a less meaningful one, such as the number line.

From both the analyses of quality and creativity of students' posed problems, it emerged that a fundamental factor for students when posing their problems, is that the problems posed must be set in a realistic context, i.e. experientially meaningful for them. When the given context for a semi-structured problem-posing activity is not meaningful for students, the same students take some elements from the context and pose problems in other realistic situations. These situations are meaningful for them reflecting their personal school or real-life experience, as suggested by the problems reported in Table 5. In this study, this process of context re-construction was possible because no constraint was explicitly made during the problem-posing activity where students had to refer to the number line when posing problems. The only constraint was to pose at least three problems (dealing with fractions) *from* that context, and not *in* that context.

In conclusion, in reference to the research question, the study showed that there was no significant difference in students' level of creativity between a real-mathematical and a real-life context. Instead, significant differences occurred in terms of *context* and *not context related* problems. Indeed, when students had to pose problems from a real-mathematical context, they constructed a new realistic setting for their problems. This finding suggests that it seems fundamental that the contexts within which students set their problems should be experientially significant for the students themselves. When the context is not significant, students attach a new meaning to it, not working with the given context but using some elements from it to build a new realistic context. Therefore, to best support students in posing their problems, the significance of the context appears to be an important factor, in increasing the opportunities in making connections between mathematics in and outside the classroom, and in helping students make sense of their mathematical activity.

This exploratory study represents an initial contribution to the study of the importance of contexts in problem-posing activities, with a specific focus on students' creativity. However, since the research is based on a small-scale sample, the results are not generalizable without further research. Future case studies are needed to validate the scheme proposed for the analysis of students' creativity and to generalize the results achieved in the current study. Other limitations of the present study suggest possible directions for future research, specifically:

- regarding creativity, compared to Guilford's (1959) model, only the components of fluency and flexibility were considered in the present study, first assessing the number of problems posed by students and then defining a level of creativity for each student. In future, how to evaluate the originality component should be investigated, in order to have a more complete analysis of creativity in relation to Guilford's model;

- in the choice of the contexts for the problem-posing activities reported in this study, the number line was considered a priori as experientially significant for students, since it was familiar to them from their previous school mathematics practice. However, as shown by the results, this context was not recognised as significant by the students, who, instead, posed problems using the data present in the number line to recreate a new context more meaningful to them. This highlights how complex it is to establish a priori the significance of a real-mathematical context. For future research, it seems important to investigate how to evaluate the significance of a given mathematical context for the students in our classrooms. In addition, other types of problems could also be considered and compared to the two proposed here, such as animated scenarios (Russo & Russo, 2020);
- in defining the level of creativity associated with a student, comparability or differentiation was controlled only within the experiment data. Starting from the proposed data analysis scheme, future research students' responses should also be analysed in terms of patterns of problems common in their classroom or textbooks, investigating the role of the *didactic contract* (Brousseau, 1988) in a problem-posing activity.

To conclude, the aim of this study was to start investigating the impact of different contexts on some aspects of problem-posing (creativity), and not to compare the frameworks of RME and Palm in terms of real contexts. What emerged from the study is that artefacts, closer to Palm's framework, appeared to be more familiar to students, viewing them as more realistic. The key point is that to make sense of their mathematical activity, students look for meaningful contexts, and this characteristic is actually required by both proposed frameworks. However, from this analysis another consideration appears: it seems difficult to make students familiar with contexts that come from mathematics. We believe that this could be a great challenge for the future, since these kinds of contexts can offer significant starting points for vertical mathematization as well (Freudenthal, 1991; Treffers, 1987).

References

Albarracìn, L., & Gorgoriò, N. (2019). Using Large Number Estimation Problems in Primary Education Classrooms to Introduce Mathematical Modelling. *International Journal of Innovation in Science and Mathematics Education, 27*(2), 45–57.

Bonotto, C. (2013). Artifacts as sources for problem-posing activities, *Educational Studies in Mathematics, 83*(1), 37-55.

Bonotto C., Dal Santo L. (2015). On the Relationship Between Problem Posing, Problem Solving, and Creativity in the Primary School. In: Singer F., F. Ellerton N., Cai J. (Eds.), *Mathematical Problem Posing. Research in Mathematics Education*. New York: Springer.

Borasi, R. (1986). On the nature of problems, *Educational Studies in Mathematics, 17*, 125-141.

Brown, S.I., & Walter, M.I. (1990). *The art of problem posing*. Hillsdale: Lawrence Erlbaum.

Brousseau, G. (1988). Le contrat didactique: le milieu [The didactic contract: The milieu]. *Recherches en Didactique des Mathématiques, 9*(3), 309–336

Cai, J., & Hwang, S. (2002). Generalized and generative thinking in U.S. and Chinese students' mathematical problem solving and problem posing. *Journal of Mathematical Behaviour, 21*(4), 401-421.

Cai, J., Hwang, S., Jiang, C., & Silber, S. (2015). Problem-Posing Research in Mathematics Education: Some Answered and Unanswered Questions. In Singer F., F. Ellerton N., Cai J. (Eds.), *Mathematical Problem Posing. Research in Mathematics Education* (pp. 3-34). New York: Springer.

Chen, L., Van Dooren, W., Chen, Q., Verschaffel, L. (2011). An Investigation on Chinese Teachers' Realistic Problem Posing and Problem Solving Ability and Beliefs. *International Journal of Science and Mathematics Education, 9*, 919-948.

Christou, C., Mousoulides, N., Pittalis, M., Pitta-Pantazi, D., & Sriraman, B. (2005). An empirical taxonomy of problem posing processes. *Zentralblatt fur Didaktik der Mathematik, 37*(3), 149-158.

Ellerton, N.F., Singer, F.M., & Cai, J. (2015). Problem Posing in Mathematics: Reflecting on the Past, Energizing the Present, and Foreshadowing the Future. In: Singer, F.M., Ellerton, N.F., Cai, J. (Eds.), *Mathematical Problem Posing. Research in Mathematics Education.* New York: Springer.

Freudenthal, H. (1991). *Revisiting mathematics education. China lectures.* Dordrecht: Kluwer

Gravemeijer, K. & Doorman, M. (1999). Context Problems in Realistic Mathematics Education: A Calculus Course as an Example, *Educational Studies in Mathematics, 39*(1-3), 111-129.

Guilford, J.P. (1959). Traits of Creativity. In H.H. Anderson (Ed.), *Creativity and its cultivation* (pp.142-161). New York: Harper & Brothers Publishers.

Kontorovich, I., Koichu, B., Leikin, R., & Berman, A. (2011). Indicators of creativity in mathematical problem posing: How indicative are they? In M. Avotina, D. Bonka, H. Meissner, L. Sheffield, & E. Velikova (Eds.), *Proceedings of the 6th International Conference Creativity in Mathematics Education and the Education of Gifted Students* (pp. 120–125). Latvia: Latvia University.

Kopparla, M., Bicer, A., Vela, K., Lee, Y., Bevan, D., Kwon, H., Caldwell, C., Capraro, M.M., & Capraro, R. M. (2019). The effect of problem-posing intervention types on elementary students' problem-solving. *Educational Studies*, *45*(6), 708-725.

Lee, S.Y. (2020). Research Status of Mathematical Problem Posing in Mathematics Education Journals. *International Journal of Science and Mathematics Education*, https://doi.org/10.1007/s10763-020-10128-z.

Leung, S., & Silver, E.A. (1997). The role of task format, mathematics knowledge, and creative thinking on the arithmetic Problem Posing of prospective elementary school teachers. *Mathematics Education Research Journal*, *9*(1), 5-24.

National Council of Teachers of Mathematics (2020). *Principle and Standard for School Mathematics*. Reston: Va, NCTM.

Palm, T. (2006). Word problems as simulations of real-world situations: a proposed framework. *For the Learning of Mathematics*, *26*(1), 42-47.

Passarella, S. (2021a). Emergent modelling to introduce the distributivity property of multiplication: a design research study in a primary school, *International Journal of Mathematical Education in Science and Technology*, https://doi.org/10.1080/0020739X.2021.1910869

Passarella, S. (2021b). Mathematics Teachers' Inclusion of Modelling and Problem Posing in their Mathematics Lessons: an Exploratory Questionnaire, *European Journal of Science and Mathematics Education, 9*(2), 43-56. https://doi.org/10.30935/scimath/10773

Russo, J. (2019). Walking the Line between Order and Chaos: a Teacher-Researcher's Reflection on Teaching Mathematics with Challenging Tasks in Primary Classrooms. *International Journal of Innovation in Science and Mathematics Education, 27*(3), 14-24.

Russo, J.; Russo, T. (2020). Movies through a mathematical lens. *Australian Primary Mathematics Classroom*, *25*, 20–26.

Silver, E. A. (1994). On mathematical problem solving, *For the Learning of Mathematics, 14*(1), 19-28.

Silver, E. A. (2013). Problem-posing research in mathematics education: looking back, looking around, and looking ahead. *Educational Studies in Mathematics, 83*(1), 157–162.

Singer, F.M., Ellerton, N.F., & Cai, J. (2015). Mathematical problem Posing Today: A Cross-Cultural View. In F.M. Singer, N.F. Ellerton, & J. Cai (Eds.), *Mathematical Problem Posing. From Research to Effective Practice* (pp. vii-x), New York: Springer.

Stoyanova E., & Ellerton N. F. (1996). A framework for research into students' problem posing in school mathematics, In P. C. Clarkson (Ed.), *Technology in mathematics education* (pp. 518–525), Mathematics Education Research Group of Australasia: The University of Melbourne.

Torrance, E. P. (1966). *Torrance tests of creative thinking*. Princeton: Personal Press.

Treffers, A. (1987). *Three dimensions. A model of goal and theory description in mathematics instruction-the Wiskobas project*. Dordrecht: Reidel Publishing.

Van den Heuvel-Panhuizen, M. (2005). The role of contexts in assessment problems in mathematics. *For the Learning of Mathematics, 25*(2).

Van den Heuvel-Panhuizen, M., & Drijvers, P. (2014). Realistic Mathematics Education, In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 521-525). Dordrecht, Heidelberg, New York, London: Springer.

Van Harpen, X.Y., & Presmeg, N.C. (2013). An Investigation of Relationships between Students' Mathematical Problem-Posing Abilities and Their Mathematical Content Knowledge. *Educational Studies in Mathematics*, *83*(1), 117-132.

Van Harpen, X. Y., & Sriraman, B. (2013). Creativity and mathematical problem posing: an analysis of high school students' mathematical problem posing in China and the USA. *Educational Studies in Mathematics, 82*(2), 201–221.

Xie, J, & Masingila, J.O. (2017). Examining Interactions between Problem Posing and Problem Solving with Prospective Primary Teachers: A Case of Using Fractions. *Educational Studies in Mathematics, 96*, 101-118.