THINKING INSIDE THE POST: INVESTIGATING THE DIDACTICAL USE OF MATHEMATICAL INTERNET MEMES

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We venture in the almost unexplored field of mathematical Internet memes, with the aims of investigating their didactical features in a teaching and learning setting. The work is framed within the research field studying the links between emotions and mathematical thinking and takes off with a schematization of the meanings carried by a meme, formulated through an a-priori analysis of spontaneous web productions and results of an exploratory experiment. The analysis is then compared to the data collected in a teaching experiment conducted at high school level. Results sustain the conjectured meanings structure and elicit evidence of students' emotions and of their role in the learning process initiated by the interaction with memes.

INTRODUCTION: MEMES AS NEW LEARNING OBJECTS

We argue that mathematical Internet memes can morph into effective learning objects if paired with adequate teaching practices, pointed at harnessing memes' social, emotional and communicative potentials and funnel them into teaching and learning assets. The present study aims at verifying the robustness of an a-priori schematization of the meanings carried by memes and test their didactical use in a learning setting.

WHAT IS A MATHEMATICAL INTERNET MEME

Mathematical Internet memes are a special kind of Internet memes, which in turn are a subset of memes, "unit(s) of cultural transmission" that propagate themselves by imitation [Dawkins, 1976, p. 249]. The common feature that characterizes Internet memes is that they are pieces of digital media that spread virally through social channels, reaching a large audience in a very short time. They are built of "verbal and pictorial parts, which unfold their meaning through collective semiosis" [Osterroth, 2018, p. 6] they can be in the form of viral images, videos or files created by users following collectively established rules that govern the so-called *memesphere* and they are widely shared through social platforms with a satirical or humorous intent. According to Shifman [2014, p. 15] "while seemingly trivial and mundane artefacts", memes "reflect deep social and cultural structures" and "epitomize the very essence of the so-called Web 2.0 era". Although they score an ever-increasing number of appearances on social platforms (the hashtag #memes hit 67 million of occurrences on Instagram in January 2019), they can be called *famous strangers:* well known to net citizens worldwide, but

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Fig. 1. Original template (1*a*) and mathematical variations (1*b* and 1*c*)

totally foreign for those who are not familiar with social media culture. As a matter of fact, up to now, they are understudied by academic research.

We start with a web found example: in Fig. 1*a*, we see the original viral image of the *Who Killed Hannibal?* meme, Fig. 1*b* and 1c show two mathematical variations.

Which information is necessary to understand them? First, we need to recognize them as memes. Second, we have to connect some evidence to the background image: we should know the original image to identify the remixing in the mathematical variations. In Fig. 1*b* Hannibal is unaffected by the shooter and in 1c he doubles himself as a consequence of being shot at. Third, we have to understand the mathematical meanings represented symbolically: in 1*b* the notion that the exponential function $y = e^x$ remains untouched by the differential operator and in 1*c* the fact that $y = e^{2x}$ doubles when the first derivative is taken. In our preliminary web survey on social media, we have encountered dozens of mathematically-themed groups, with hundreds of users reacting, commenting and questioning about the image or the mathematical part of memes like the one analysed here. This suggests that only those who succeed in grasping all levels fully understand the meme, laugh and feel part of this mathematically skilled community that emerged spontaneously in the digital world.

THE MEANINGS OF A MEME

In a previous study [Bini, Robutti, 2019], through the a-priori analysis of web productions and the results of an exploratory experiment, we identified three partial meanings that build up the full meaning of an Internet meme:

- The first partial meaning is *structural* and lies in its being a meme, namely to have a specific and shared structure and graphics (font, colour, text position).
- The second partial meaning is *social* and lies in the shared conventions of viral images, compositional setups and syntaxes (Fig. 1*a*).
- The third partial meaning is *specialised* and lies in images, symbols or text referring to a specific topic (mathematical, or other) (Fig. 1*b* and 1*c*).

The first two meanings ground in the popular culture rules that govern the *meme-sphere*, while the third calls some mathematical knowledge and skills into action. The interplay of all three *partial meanings* is needed to unlock what we call the *full meaning* of the meme, which triggers a sense of surprise and fun. Here we intend meaning within a "sphere of practice", adhering to a common set of rules, where "mathematical meanings are constructed" [Kilpatrick et al., 2005, p. 10].

For students, who are fully fledged net citizens and access the first two meanings easily, the obstacle in grasping the full meaning usually lays in understanding its specialised meaning (the mathematical content). In an educational setting, we hypothesise that this final hurdle, that makes the act of cracking the meme even more rewarding, could turn out as one of the meme's significant didactical feature. In fact, the introduction of some attuned *desirable difficulties* in the learning process can improve long-term retention, since "in responding to the difficulties and challenges, the learner is forced into more elaborate encoding processes and more substantial and elaborate retrieval processes" [Bjork, 1994, p. 192]. On the other hand, teachers — who are usually not familiar with social media trends — may be shut out of the first two meanings, and therefore of the full meaning of the meme. This can be called an *undesirable difficulty* that creates a barrier between teachers and students, grounding on the digital culture vs. school culture cliché. This paper aims at opening a breach in this barrier, introducing the idea of *didactical meme*: a mathematical Internet meme used in the classroom for teaching and learning purposes.

THEORETICAL FRAMEWORK

Memes are a totally new phenomenon in mathematical education research and there is no history in literature of suitable theories to frame them. Our first exploratory approach [Bini, Robutti, 2019] was based on the results of an a-priori analysis of memes and aimed at describing their role in education from a cognitive point of view. The Boundary Object perspective, as introduced by Star, Griesemer [1989], and Sfard's [2008] theory about discourse and communicational approach to cognition seemed appropriate to ground our analysis on.

Further investigations, involving new data on the memes design process (described in the *Data and analysis* paragraph), steered our focus from the cognitive to the emotional aspects of students' interplay with memes. We were faced with evidence that "emotions also affect cognitive processing in several ways: they bias attention and memory and activate action tendencies" [Zan et al., 2006, p. 118]. The cultural-historical approach introduced by Radford [2015], a "cultural conception of emotions and their role in thinking in general and mathematical thinking in particular" [p. 26], seems fit for our case. In fact, according to Radford, emotion and thinking are strictly connected: "from a cultural-historical perspective, emotions are both subjective and cultural phenomena simultaneously; they are entrenched in physiological processes and conceptual and ethical categories through which individuals perceive, understand, reflect, and act in the world" [p. 35]. In particular, his idea that "contemporary cultural ideas of learning and learners are conveyed by schools and other social institutions, family, and mass culture" [Radford, 2015, p. 46] valorize the social value of memes, which, through shares and likes, act as social currency in the memesphere.

To sum up, using the words of an anonymous Reddit user, memes are "like inside jokes between millions of people": they find their reason for being in reactions and root deeply into emotions. We argue that a didactical meme can be a conveyor of cognitive and emotional elements, taking advantage of a fact neural scientists agree on, i.e. that "emotional arousal often leads to stronger memories" [LeDoux, 2007], as memories about emotional situations are normally stored both in explicit and implicit memory systems. The research questions of the study are: RQ0) What is the students' familiarity with social platforms and memes? RQ1) Are the meanings of didactical memes recognised by students the same as we described in the a-priori analysis? RQ2) What is the role of emotions in a learning process involving didactical memes?

METHODOLOGY

This work presents the pilot study of a PhD thesis (one of the authors'), involving a class group of 22 10th grade students, who created their own didactical memes on the topic of linear systems and recorded videos with the explanations of the specialised meaning. Due to page restriction, didactical memes involved in the study will be now on referred to simply as memes. Data collected are: individual entry forms and worksheets, memes and videos created at school by students working in pairs (3h), screencast and video recordings of the memes and videos production processes by two selected pairs, individual feedback forms and reflective worksheets, video recordings of the collective discussion guided by the teacher (2h). Observed pairs were picked out coupling students with mixed mathematical and linguistic abilities, to facilitate the emergence of the expected meanings and their interaction. Students' creations have been gathered in collective spaces (Padlet walls shared via Google Classroom) that mimicked the social media environment, allowing the coveted reactions.

DATA AND ANALYSIS

The entry online form answered RQ0, assessing that 100% of the students were familiar with social platforms (83% declared to visit them "several times a day"), with memes ("an image with funny text") and had some interaction with general purpose (i.e. non-didactical) memes (100% declared to like and/or share them on social platforms, one student identified himself as a meme creator). The entry worksheet, administered by the teacher, used the meme in Fig. 2 to check if our a-priori identified partial meanings matched those recognised by students.

All answers support our a-priori analysis of the partial meanings of a meme (RQ1). In Table 1 we show expected partial meanings (not revealed in the questionnaire), questions, and samples of students' answers (selected because particularly effective).

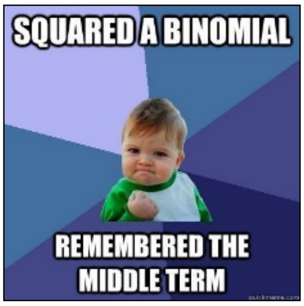
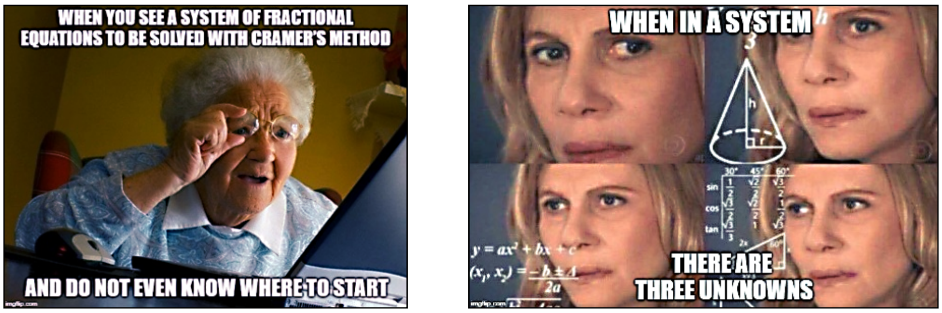


Fig. 2. The entry worksheet mathematical meme

Table 1

Assessment of the meanings of a meme

Meaning	Questions	Answers
Structural	In your opinion, what leads you to say that this is a meme and not a cartoon?	S1: From the classic meme font, that is in capital letters, and the fact that it is divided into two parts, a sentence above and one below that do not cover the image
Social	What do you think is the purpose of the image chosen as the background of the meme?	S2: The child's gesture means "hurray I've done it" and implies that, as finding the middle term is difficult, when you do you are happy
Specialised	Which mathematical topic is referred to in this meme?	95% identified and explained the rule applied to square a binomial and 81% agreed on the fact that the middle term is usually forgotten



a *b*

Fig. 3. Pilot study focus couples' memes (captions translated by authors)

Subsequently, we analysed the products (Fig. 3*a* and 3*b*) and the production processes of the two focus pairs, to identify the interaction between partial meanings.

All memes were created through a Meme Generator website that automatically imposes the compositional rules, so we shall take the structural meaning for granted and focus on the interplay of the social and specialised ones. Hereafter we summarize the key moments of the selected pairs' memes production processes.

Figure 3*a*: pair 1 (two girls) started with the idea of creating a meme on what they identified as the most difficult aspect of the assigned topic (specialised meaning: Cramer's rule and fractional equations). In the Meme Generator website, they looked for a template whose social meaning matched the emotion that these mathematical difficulties stirred. In the explanatory video, they connected the two meanings, clarifying that "the expression of the old woman in the meme represents our faces when we see [simultaneous] fractional equation to be solved with Cramer's rule".

Figure 3*b*: pair 2 (two boys) browsed through the various templates in the website, laughing and quoting a variety of possible captions related to their feelings and experienced difficulties in mathematics (fractions, binomial expansions, systems), to create something funny and original ("in my opinion everybody will use the first [images], we could differentiate ourselves…"), because if the template and/or subject were already used by someone else, there would be less chance of gaining likes.

In both cases, grounding on the shared structural level, we witness something that we did not consider in our a-priori analysis: a dynamic interplay between social and specialised meanings in the design activity, deeply rooted on emotions (Fig. 4).

Pair 1 follows the left-pointing red arrow and pair 2 the right-pointing black arrow, but in both cases students' facial expressions, choice of words and physical reactions showed that emotions — aroused by a dynamic coaction of mathematical content and cultural constructs [Radford, 2015, p. 29] — enabled the connection between meanings and acted as origin and ultimate goal of the interaction with the meme (RQ2).

A similar double path illustrates the class group dealing with memes in Fig. 5, created by the researcher and presented in a worksheet the following lesson — asking students to describe their specialised meanings — as a start off for the discussion.

The meme in Fig. 5*a* was greatly appreciated ("this is beautiful"): its specialised meaning was immediately understood and connected to the social meaning through an emotional interlacing ("it looks like Viola — the smartest student in the class group — when we solve problems together"). Here the specialised meaning, i.e. the ability to recognize that the given problem is best solved using the elimination method, is processed first and then connected to the social meaning resulting in a successful didactical meme that prompted a deep collective discussion: we are moving along the left-pointing red arrow in Fig. 4 scheme.

On the other hand, the meme in Fig. 5*b* puzzled students: in the worksheet a significant share (64%) correctly described the mathematical meaning ("for the comparison method we need to apply the transitive property", "the comparison method is justified by the transitive property" (in the Italian curriculum, the comparison method refers

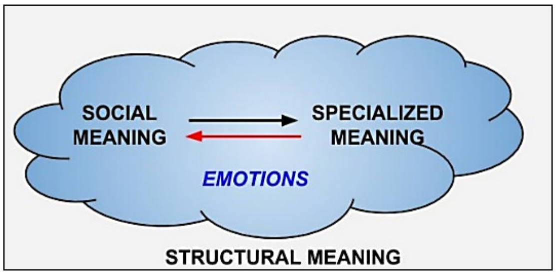
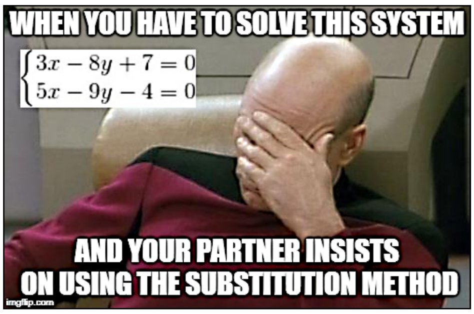
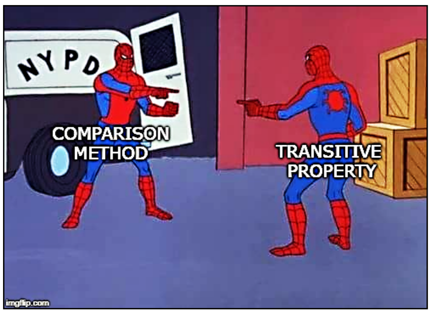


Fig. 4. The meanings interplay and the role of emotions





a *b*

Fig. 5. The reflective worksheet memes

to a 2 × 2 linear system solving technique where the same unknown is obtained from both equations and then the right-end sides expressions are joined to get a single variable equation)). Discussing the meme later, they showed mixed feelings ("I did not understand it so well because of this transitive property"). The following excerpt clarifies the unfolding of the interplay between the different meanings:

Student: No, I did not remember very well what the transitive property was.

Teacher: But looking at the meme image, what would you say?

Student: That they are two similar things, two equal things (the social meaning of the image is to describe situations in which two very similar elements meet).

Upon further inspection, the majority of the students admitted they did not remember what the transitive property was and a recap of the property was given by the teacher.

Teacher (after the recap, addressing the whole class group): The things you wrote [in the worksheet], those of you who wrote them correctly, did you write them because you remembered the transitive property or just to make sense of this meme and say that they are almost the same thing because the image tells us this?

Students yelling in chorus: Because of the meme!

Teacher: I do not know whether to be happy or not, though…

Researcher: Now that we have used this meme to recall that they are the same thing, do you think you will remember when you use the comparison method, do you think you will associate it with the transitive property more consciously?

Students in chorus: Yes, definitely.

In this case, knowledge is built moving along the black arrow of Fig. 4, from the social to the specialised meaning and emotions are deeply tangled with the whole path. Finally, in the feedback questionnaire, 81% of the students answered positively to the question whether they had learnt or understood something better ("yes, also checking at the other memes created"), 86% scored more than 7 in a 1–10 rating scale question about "having created the meme will help you remember this topic better?". In the following days, the teacher reported that "we are working on the transitive property of equality: I was amazed by my pupils' attention to names… when I explain I do not give much importance to names. But I think it's for the idea of *making a good impression*".

DISCUSSION: A NEW COGNITIVE OPPORTUNITY

To sum up, we started with an a priori analysis that led to the three meanings structure of a meme and was confirmed by students' entry worksheets (RQ1). When we observed the processes of memes' creation and interaction with them, we saw that the three partial meanings were not handled in a fixed order, but that the development is more complex and dynamic, with different access points. Students' physical reactions and utterances showed that emotions drive the relation with memes (both as creators and users) and allow shifting from the specialised to the social meaning and vice versa (RQ2). This emotional involvement turns out as the meme's most powerful affordance: from the learning point of view it guides and motivates students to understand the meme's specialised meaning. From the teaching point of view, it can be exploited by teachers who can use memes to reply to students' memes, resulting in a *memetic* adaptation of the *semiotic game* [Arzarello et al., 2009], focused on the memes' mathematical specialised meanings. This use of memes can foster language awareness and further mathematical reflections, as shown by the teacher's testimony.

Although these results seem encouraging, our work is far from complete, more investigation is needed to dig deeper into the affordances of memes: for example, a mid and long-term assessment to evaluate the connection between the emotional situations aroused by memes and students' retention of the associated knowledge. Anyway, we think that this almost uncharted territory is worth exploring, because, even if digital culture can be labelled by someone as a non-culture, facing the evidence that our students are emotionally embedded in it, we think it would be educationally valuable to embrace it and turn it into a cognitive opportunity.

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