Images of Mathematics and mathematicians among undergraduate students of Education

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ABSTRACT

In our research, we investigated the role of production of *digital mathematical performance* (DMP) in pre-service teacher education, regarding the (de)construction of images of mathematics and mathematicians. We report a qualitative case study conducted with undergraduate students of Education, whose elaborated two sets of drawings in order to artistically represent and disseminate both public and alternative images of mathematics and mathematicians. Students' drawings were used to produce artistic digital videos, conceptualized as DMPs. In terms of findings, students' public images reveal negative/stereotyped aspects. In contrast, alternative drawings depict positive/ideal images. The process of producing DMPs contributes to students' education as pre-service teachers in respect of exploration and production of pedagogic content knowledge. It also promotes changes in students' attitudes and believes about teaching and learning mathematics, engaging them into alternative forms of using digital media and the arts in mathematical activity.

Keywords: Digital mathematical performance. Digital technology. Pre-service teacher education. Public image of mathematics. Public image of mathematicians.

Imagens da Matemática e dos matemáticos entre alunos de graduação em Pedagogia

RESUMO

Na nossa pesquisa, investigamos o papel da produção de performances matemáticas digitais (PMDs) na formação de professores, pensando na (des)construção de imagens da Matemática e dos Matemáticos. Apresentamos um estudo de caso qualitativo no qual estudantes de graduação em Pedagogia elaboraram dois grupos de desenhos a fim de representar artisticamente e disseminar ambas imagens, pública e alternativa em relação à Matemática e aos matemáticos. Os desenhos dos alunos foram usados para produzir vídeos artísticos e digitais, conceituados como PMDs. Em termo de resultados, a imagem pública dos alunos revela aspectos negativos/estereotipados

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Received for publication on 23 Oct. 2017. Accepted, after revision, on 2 Dec. 2017.

em respeito à da Matemática e à dos Matemáticos. Em contraste, os desenhos que representam imagens alternativas, tendem a ideias positivas/ideais dessas imagens. O processo de produção de PMDs contribui para a formação dos alunos enquanto professores em termos de respeitar a exploração e produção de conteúdos específicos e pedagógicos. Esse processo também promove mudanças nas concepções e atitudes dos alunos com relação à aprendizagem de Matemática e ao seu ensino, ao engajá-los em formas alternativas do uso de mídia digital e Artes na atividade matemática.

Palavras-chave: Performance matemática digital. Tecnologias digitais. Formação de professores. Imagem pública dos matemáticos. Imagem pública da Matemática.

INTRODUCTION

The public image of mathematics and mathematicians is a theme discussed by author such as Furinghetti (1993), Lim (1999), Picker and Berry (2000) and Gadanidis (2012). One of the problems posed by these authors refers to the negative/stereotyped images people hold. Most students, parents, and (pre-service) teachers in several school levels, generally see mathematics as something cold, boring, inhuman, and difficult. They also see mathematicians as (authoritarian) teachers, anti-social human beings, and nerds. Sometimes, these images are related to monsters, fear, phobia, and frustration. Rarely, the public image of mathematics and mathematicians are reported as positive, human, lovely, good, and/or sublime.

According to the literature, the genesis of this problem is usually related to the learning experiences people have in schools and everyday activities (GADANIDIS; SCUCUGLIA, 2010), including the images disseminated by the media (e.g., TV shows, films, books, and so forth) (FURINGHETTI, 1993). Other aspects that foment the construction of negative images are:

- formalist/absolutist conceptual nature of mathematical knowledge in schools and society (LIM; ERNEST, 1999, 2000);
- ideology of certainty (BORBA; SKOVSMOSE, 1997);
- "traditional" classroom connectivity based on the development of individual, abstract and repetitive tasks (GADANIDIS; BORBA, 2008);
- low score achievement in tests and strict teacher-students power relations (ALENCAR; SCUCUGLIA, 2014); and
- hegemony of mathematical content knowledge in teacher education instead the emphasis on pedagogic knowledge (NACARATO, 2006).

How can we educationally act in order to deconstruct negative images and create potential alternative images of mathematics and mathematicians?

In this paper, we discuss aspects of a research in which we investigated the role of production of conceptual digital mathematical performance (DMP) in pre-service teacher education, regarding the (de)construction of images of mathematics and mathematicians. Specifically, as a qualitative case study, we present and discuss some images created by undergraduate students of Education at São Paulo State University, Brazil, aiming to explore: (1) the pedagogic nature of students' (public and alternative) images, and; (2) the potential role of DMP's production in pre-service teacher education.

We also explore the very notion of DMP as an educational alternative towards the use of digital media and the arts in Mathematics Education, focusing on the construction and dissemination of public and alterative images of mathematics and mathematicians for a wide (online) audience, beyond classrooms.

According to Lim (1999), the term image of mathematics can be conceptualized

> […] as a mental representation or view of mathematics, presumably constructed as a result of social experiences, mediated through school, parents, peers or mass media. This term is also understood broadly to include all visual, verbal representations, metaphorical images and associations, beliefs, attitudes and feelings related to mathematics and mathematics learning experiences. (LIM, 1999, p.1)

Based on this conception, Lim and Ernest (2000) state some issues emphasizing the scenario of higher education and *myths* related to the image of mathematics:

> Mathematics is a mysterious subject, and a number of myths are associated with mathematics. These myths include commonly expressed views including: "mathematics is just computation", "mathematics is only for clever people (and males)"; "your father is a maths teacher so you must be good in mathematics too". Such myths and images are widespread, are seem to be present in many countries, and among all classes of people. Moreover, most of these myths are negative [...] these negative images of mathematics might be one of the factors that has led to the decrease in student enrolment in mathematics and science at institutions of higher education. (LIM; ERNEST, 2000, p.7)

The term *image of mathematicians* can be conceptualized as the same as the image of mathematics and along different school levels and events. According to Picker e Berry (2011), investigations on what kind of images students have on mathematics and mathematicians can help teachers to understand students' attitudes in relation to mathematics, their mistakes, opinions, and feelings about the subject.

Picker e Berry (2000), based on drawings produced by 476 students from five different countries, posed that "stereotypical images of mathematicians are common to pupils in all of these countries and these images indicate that for pupils […] mathematicians and the work that they do are, for all practical purposes, invisible". Rensaa (2006) problematized the role of the media in supporting stereotyped visions of mathematics as a male professional activity. Using a survey to investigate how people imagine a mathematician, Reensa (2006) concluded that most people see a mathematician as a man working in an office or teaching in a classroom. The study suggests that the negative images people have toward mathematics condition the construction of stereotypical images people hold about professional mathematicians.

Rock and Shaw (2000) carried out a study to investigate what children think about mathematicians. They developed a voluntary research with participation of kindergarten and elementary school students. The authors directed attention to three main questions posed to students: (1) What do mathematicians do?; (2) What kind of problem do they solve?, and; (3) Which tools or instruments do they use? The findings of the study revealed the emergency of stereotyped images such as 'mathematicians work with numbers', 'solve hard problems such as 1,000,000 x 1,000,000', and 'their working tools are computers, calculators, paper, pencil, erasers, rulers, geometric shapes, blocks, fingers, hands, brain, and mind'.

Since we identified a conceptual problem towards the image of mathematics and mathematicians among students in several school levels, it also becomes a conceptual-pedagogic matter within teacher education. Accordingly to Nacarato (2006), part of the literature on mathematics pre-service teacher education states that many courses for teacher training emphasize:

> […] specific mathematical content, disregarding disciplinary knowledge […], this disciplinary knowledge, if devoided of pedagogical and curricular approaches, do not offer ways to the future teacher to instruct in basic education. (NACARATO, 2006, p.44)

Thus, potential connections between content knowledge and pedagogic knowledge (SHULMAN, 1986), such as emergent events from the exploration towards images of mathematics and mathematicians, are fundamental aspects of teacher education (SCUCUGLIA, 2016). Within this perspective, possible alternatives to disrupt negative attitudes and beliefs toward mathematics and ways to construct new positive images of mathematics and mathematicians are also discussed in the literature.

Picker e Berry (2001), for instance, states that one way to discovery students' attitudes towards mathematics "is to ask students to draw a mathematician". Gadanidis and Scucuglia (2010) also explore these aspects in the scope of the production of DMP, that is, these authors investigate the educational use of the arts and digital technology by offering ways to construct and disseminate alternate images of mathematics and mathematicians (SCUCUGLIA, 2014).

DMP regards to the integrated and innovative use of the (performance) arts and digital media in Mathematics Education (SCUCUGLIA, 2012). Nevertheless, the expression DMP is usually employed in multiple ways, as it is used to refer to a recent trend in mathematics education and as a potential didactical-pedagogical methodology for teaching and learning mathematics, including teacher education (BORBA; SCUCUGLIA; GADANIDIS, 2014).

> What if as mathematicians, as math educators, or as students of mathematics we moved outside of the domain of assessment (where performance takes on a different meaning) and used an artistic lens to look at how we 'perform' mathematics? If we view mathematics (doing, teaching, learning) as embodied performance, what do we see differently? Thinking of mathematics and mathematics teaching and learning as performance may help to destabilize and reorganize our thinking about what it means to do and teach mathematics with technology. (GADANIDIS; BORBA, 2006)

Since 2006 the research results on DMP are increasing the dialogical space and its range in the Mathematical Education's field (GADANIDIS; BORBA, 2008). Moreover, DMP assumes a semiotic meaning, considering it can also be conceptualized as multimodal artistic text/narrative utilized to communicate/represent mathematics through the arts and digital media (SCUCUGLIA, 2012).

The most common types of DMPs are digital videos in which students and/or teachers communicate mathematical ideas through poetry, music, theatre, dance, cinema, and other artistic expressions. These videos are publicly available online in virtual environments such as the YouTube and educational platforms like the *Math + Science Performance Festival* (see http://www.mathfest.ca).

We consider a learning environment that explores DMP as a didactical-pedagogical possibility towards the pre-service teacher education. The DMPs produced and analyzed in this research are video clips (digital videos) in which the storylines use the images created by the participants, whose intend to offer surprises to the audience by contrasting the public/stereotyped/negative images and the alternative/positive images. Moreover, through a retrospective analysis on the use of technology in Mathematics Education, Borba, Scucuglia and Gadanidis (2014) argue that we live in a *fourth phase* nowadays.

> The fourth phase can be characterized by: (a) arising of GeoGebra software, which transformed qualitatively the second phase as it integrated dynamic geometry and graphical software in the same computer platform; (b) arising of fast Internet which allowed files and multimodal texts, mainly digital videos to be supported and shared; (c) portable digital technologies accessibility through the Internet, like laptops, tablets, mobile phones, digital cameras, etc.; (d) Internet usage in face to face classroom; (e) emergence of DMP notion and its production. (BORBA; SCUCUGLIA; GADANIDIS, 2014, p.24)

Thereupon, DMP can be considered as a currently perspective on Mathematics Education in terms of the use of digital technologies in mathematics teaching and learning, including pre-service and in-service teacher education (GADANIDIS; BORBA, 2008). In the midst of diversified aspects, literature on teacher education addresses the lack of courses that explore the construction of formative environments, promoting the use of digital technology and the production of pedagogic content knowledge (SCHULMAN, 1986).

Therefore, in this study, we investigate and explore these perspectives on DMP and teacher education in relation to the image of mathematics and mathematicians elaborated by undergraduate students of Education.

METHODS

In the scope of the research, methodology has a qualitative nature (DENZIN; LINCOLN, 2006). Production and analysis of data involve different perspectives like audiovisual recording in a university's mobilization knowledge course, case study, video analysis, conceptual DMP analysis, semi structured interviews, application of surveys and questionnaires, and creation of artistic representation in learning activities (FINLEY, 2005).

In the specific context of the data discussed in this paper, the methodological perspective emphasized is *qualitative case study* (STAKE, 2000a). Accordingly to Ponte (2006),

> [Case study is] an investigation that assumes itself as particularistic, i.e., it deliberately addresses a specific situation that supposedly is unique or special, at least in some aspects, looking for the discovery of what is the most essential and characteristic in it and, thereby, contributing to the global comprehension of a certain important phenomenon. (PONTE, 2006, p.2)

Altogether, the main research question explored in this article is: what are images of mathematics and mathematicians constructed by pre-service teachers? In a specific and/or exploratory way, we can pose: what are the public images of mathematics and mathematician in students' views and how do they think ideal images should be? What is the role of the production of DMPs in the process of construction and/or deconstruction of (public and ideal) images amongst pre-service teachers?

In order to produce data for this study we invited thirty-six undergraduate students of Education enrolled in the course "Content and Methodology of Mathematics Teaching" at Sao Paulo State University, Brazil, to participate voluntarily in a learning activity as part of the development of an exploratory research within a knowledge mobilization course. The participants were enrolled in a four-year teacher education program that offers course work, specialization, and classroom practice focusing on teachers' professional engagement in preschool and primary school. Within the 3.400 hours of the program, the course "Content and Methodology of Mathematics Teaching" takes 60 hours in the second-year of the program structure, focusing on exploration of mathematics contents of elementary and high school and teaching methodologies such as problem solving, use of technology, game and playfulness, and history of mathematics. The admission requirement for this program is to be a high school graduate and to be approved in the university assessment tests. Students' ages, previous studies, interests, and social background and experiences were not investigated in this study due to the initial research aims and the university ethics protocols as well.

As the pre-service teachers were warned of the activity's nature, we asked them to create two sets of drawings to produce digital videos as DMPs within an eight-hours knowledge mobilization course within the sixty-hour course. In the first 4 hours of activities, we presented to students the notion of DMP (SCUCUGLIA, 2012) and we discussed collectively the theme public image of mathematics and mathematicians. In this first face-to-face session, we proposed to students to produce 4 drawings organized in 2 set as it follows:

The objective of the first set of drawing was to represent *public images* of mathematics and mathematician. They had represented artistically images of mathematics and mathematician most people have, in their view. Thus, the participants were engaged in an activity in which they should express through visual arts an answer to the following question: What are the public images of mathematics and mathematicians?

The aim of the second set of images was to represent artistically *ideal images* of mathematics and mathematicians, i.e., an alternative image in relation to (1), expressing how people could see mathematics and mathematicians in their opinion: what would be alternative images of mathematics and mathematicians? Along the teaching activity, we emphasized in our speech the use of the word "alternative", which naturally we recognize it influenced students' responses/drawings in (2).

In the second session of the knowledge mobilization course (4 hours), students finished and shared their two sets of drawings. Participants were warned that their drawings would be used in the production of DMPs about the public image of mathematics and mathematicians. Moreover, one communicated the objective of the storyline of the DMPs was to portray *surprises* to the audience, displaying, firstly, general-known *public images* and, then, *alternative images*. Along the course, DMP was discussed and explored in classroom as a potential methodology for teaching and learning mathematics, grounded in the integrated and innovative use of arts and digital technology (SCUCUGLIA, 2012, BORBA; SCUCUGLIA; GADANIDIS, 2014).

Along the development of the activities with the participants we emphasized the exploration of public images of mathematics and mathematicians in students' views instead students' personal views of mathematics and mathematicians. Through the process of construction of images in the research activities, the participants discussed and shared their personal views as well as their opinions of the public, but we highlighted the artistic creation of public images, according to our conception within the literature (LIM, 1999). We registered in video the dialog among the students whose were creating the drawings. In our analysis, for a future study, we will ask students to collect drawings from people from their surroundings. We believe this approach will improve the social dimension of the public images collectively created and shared.

Students' drawings were organized in two different ways. First, we elaborated a chart displaying each drawing in four columns (1 = public image of math; 2 = alternative image of math; 3 = public image of mathematicians and; 4 = alternative image of mathematicians). Based on the chart, we could compare students' drawing along different categories. Second, we used the drawings of 1-2 and 3-4 to produce two DMP. The narrative structure of these DMP is discussed in the following section.

Since DMP refers to the use of the arts in mathematics education, we extend such a notion in this study in the matter of the research development and its report using the arts as well. Thus, we also present part of the results of this study through the elaboration of poems. This methodological approach is supported by the very notion of *arts-based research* (FINLEY, 2005). We shared the link of the produced DMPs with the participants, asking them by a questionnaire the following question: "What is relevance of the DMPs to the production of pedagogic content knowledge?" The aim of question was to engage the participant in reflections towards Schulman's (1986) categories, since these perspectives on teacher education are part of the Education program students were enrolled. We use students' answers to discuss aspects of the role of conceiving DMPs in pre-service teacher education (BORBA; GADANIDIS, 2008).

RESULTS AND DISCUSSION

Among the thirty-six students invited (n_0 = 36), twenty (n = 20) participated in this research, sending their drawings to us via email (digitalized document) or handing an artistic work in a sheet of paper or similar material. Data was initially organized in a board as its first column presented the public images and the second column comprised ideal images created by the students. The tabular organization of data allowed a comparison/contrast between drawings of the same participant, between drawings of different participants over the same theme, and between different themes of different participants.

Public image of mathematics

Here are the visions
About Mathematics
Cold disquisitions
Boring tactics
Hovering precisions

Oversupply frantic
Endless frustrations
As lack romantic
Vivid cognition
Missing fantastic
Gorgeous solutions
(Image of Mathematics – Gabriel Gregorutti)

Accordingly to Furinghetti (1993), Lim (1999) and Lim and Ernest (1999), the public image of mathematics is linked to characteristics such as hard, cold, abstract, boring, pure, inhuman, rigorous, and formalists. In contrast with these aspects, these authors also stress that mathematics can be revealed as positive. However, we did not find these positive images when we look into the research results and findings within the literature.

In this study, two of the drawings created by the students (frequency = 2) within the *public image axis* represent mathematics as a sad or boring science. Thirteen drawings (frequency = 13) report mathematics as a monster, a science related to doubt, fear, and pain. The other five drawings (frequency = 5) stress mathematics as a cold discipline, with pictures showing a lack of color, related to stressful situations. In Figure 1, we present some of the public images of mathematics created by the students.

FIGURE 1 – Students' public (negative) images of mathematics.

Source: Research data – students' drawings.

We highlight two main aspects in our findings:

1. All the drawings made by the students toward the public image of mathematics – *how people see mathematics in the opinion of the undergraduate students of Education* –

express negative images. The three categories that emerged from the data – *sad, monster* and *cold* – do not refer to positive images, attitudes and beliefs toward mathematics. Although images of mathematicians can also be found in these drawings, we only analyze the "mathematician aspect" regarding the next set of images/data.

2. The types of images created by the students are similar to those found in other research results. However, the nature of the categorization emerged from data we propose is different. Lim and Ernest (2000), for instance, present the following set of categories:

> Five main categories of responses emerged from the analysis. They are (a) attitudes towards mathematics and its learning; (b) beliefs about respondents' own mathematical abilities; (c) descriptions of the process of learning mathematics; (d) epistemology and views of the nature of mathematics; and (e) values and goals in mathematics education. (LIM; ERNEST, 2000, p.9)

Therefore, in terms of the *public image of mathematics*, we found only negative images. We also found similarities in relation to the literature in terms of the nature of the images created and differences in terms of the nature of the categories emergent from data.

Alternative images of mathematics

We could not find in the literature alternative or ideal/positive images of mathematics as researcher findings. It does not mean that it does not exist necessarily, but it is considerably rare regarding our analysis. Thus, we propose in this section three categories of *alternative images* of mathematics considering the drawings of twenty students (n = 20), whose participated in this research.

Eight drawings (frequency = 8) created by the participants represent mathematics as a science that inspires good feelings, such as love or happiness. This category has a connection to the second one, as mathematics done creatively and colorfully offer ways to welfare sensations (frequency = 5). Ideal images of mathematics are also pointed out as useful or solution to everyday life problems (frequency = 7). Thus, the three categories emergent from data on the alternative images of mathematics are: *lovely, lively* and *useful* (see Figure 2).

FIGURE 2 – Students' alternative images of mathematics.

Source: Research data – students' drawings.

In contrast to the *public* images of mathematics, all the images constructed as *alternative* images of mathematics were positive in this study. Actually, some of the public images may be considered positive or non-negative, but we did not find negative images among the alternative images created. We argue this contrast is a consequence of the production of the video DMP, since the storyline of the proposed work with DMP in classroom seek to emphasize it. In other words, even if some of the public images are not negative, the structure of the digital narrative intends to display alternative images as positive contrasting to the public images as most negatives. Connecting the visual arts (drawings) to video and music (digital video clip produced with the images), one of the main intentions in producing the DMPs was to offer to the (online) audience a *surprise* through the contrast of public images of mathematics and alternative/positive images of mathematics. We believe this (de)constructing process of images of mathematics based on the production of DMPs is significant to pre-service teacher education in the context of the undergraduate students' learning process. The DMP on the images of mathematics produced in this is study available at https://youtu.be/GVvpCSlzjDs.

Public image of mathematicians

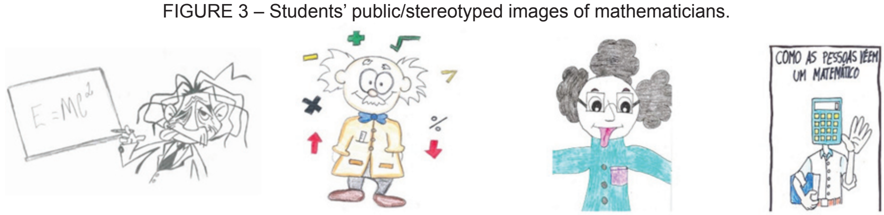
Discussing the image
Of mathematicians
People say they`re frigid
Sometimes intelligent magicians
Or monstrously rigid
Different of musicians
As lacks creativity
Even if smart logicians
They look sadly sickened
Instead of great technicians
(Multiple images – Gabriel Gregorutti)

In terms of public image of mathematicians, amongst the 20 participants (n = 20), six (frequency = 6) demonstrated an image of “Einstein effect”, according to the category stated by Picker and Berry (2000), which refers to mathematicians depicted as the physicist Albert Einstein. Five images (frequency = 5), including some of the “Einstein effect”, reported the place of work of mathematicians as a classroom. Amongst these images, the great majority of them demonstrated that the classroom environment is associated to something cold or negative, with people/students showing sad countenance or with a place filled with objects instead of people. Two pictures (frequency = 2) pointed out to mathematicians as authoritarian or upset people/professionals. A mathematician portrayed as “crazy”, “lunatic” and/or “nerd” showed up in six drawings (frequency = 6). Such images are common in the media and in movies like “A beautiful mind”, which reports the life story of the mathematician John Nash, emphasizing his schizophrenia.

Four drawings (frequency = 4) related the image of mathematicians with something monstrous or with a villain. Only one picture (frequency = 1) associated the image of mathematicians with a calculator and/or a scientist. Predominantly, the participants linked the image of mathematicians with a male activity. Only one drawing (frequency = 1) portrayed the image of a woman as a professional mathematician. Rensaa (2006), for instance, states “the female mathematicians are rarely seen by the man in the street and a mathematician is understood to have lack of social skills.”

We should point out that eight participants (frequency = 8) did not drew their own images, that is, they presented images created by other people, most of them downloaded from the Internet. In Figure 3, we report the main pictures toward the public image of mathematicians in the vision of the participants.

FIGURE 3 – Students’ public/stereotyped images of mathematicians.



Source: Research data – students’ drawings.

Based on the drawings of the 20 students (n = 20), we argue that public image of mathematicians are not significantly different of the set of images presented by researches in the field, i.e., this study corroborate with the results found in literature. The majority of the images are not necessarily negative, as the public images of mathematics are. However, the public images of mathematicians found in this study are fully stereotyped.

Thus, we may relate these images to the categories posed by Picker and Berry (2000), whose proposed seven categories in order to identify similarities between drawings of mathematicians of students from different countries:

(1) Mathematics as coercion: students see mathematicians as teachers who use intimidation and violence in order to teach the subject;

(2) The foolish mathematician: depict as lacking of fashion and common sense;

(3) The overwrought mathematician: depict as looking wild;

(4) The mathematician who can't teach: a classroom is drawn which the mathematician cannot control students' behavior; he/she is also portray as someone who does not know the subject;

(5) Disparagement of mathematicians: depict as being too clever;

(6) The Einstein effect: mathematicians are depict as the physicist Albert Einstein;

(7) The mathematician with special powers: include wizardry, magic and usage of special potions.

Connections with monsters and villains are also displayed in the drawings within categories (1) and (5). Category (6) is associated with an icon in terms of a person who is an expert in terms of mathematical knowledge and scientific-academic geniality. Usually, these images are influenced by media, including books, cartoons and movies (FURINGHETTI, 1993). Category (7) is related to the lack of comprehension by the students in classroom who think the teacher is a magician as the mathematical activity can be discovered only with something extraordinary similar to illusionism. Thereupon, we conclude that the public images of mathematicians created by the participants are not significantly different in relation to the categories elaborated by Picker and Berry (2000) and to the literature on this thematic in general (PICKER; BERRY, 2000; RENSAA, 2006; ROCK; SHAW, 2000).

Alternative images of mathematicians

The second set of images created by the pre-service teachers – how should be the ideal images of mathematicians in your opinion – is comprised by images that deconstruct, generally, the negative images presented in the past theme (public image of mathematicians). In this context, students choose to draw images related to "good" characteristics or qualities like: mathematician as a good teacher, a classroom filled with happy people, laughing, playing, having fun as they realize pleasant/human activities; these aspects could be identified in at least nine pictures (frequency = 9).

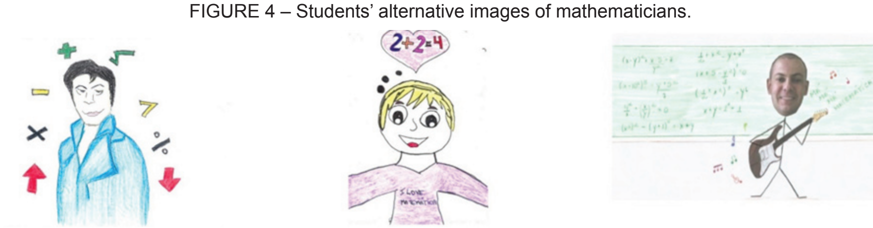
Three drawings (frequency = 3) report likewise previous category, the work of mathematician linked with the one of a scientist, in other words, one professional of natural sciences' field such as physics, biology and chemistry. In contrast with previous category, eight pictures (frequency = 8) presented woman (RENSAA, 2006) related to mathematics worker as an ideal image constructed by the participants.

Four drawings (frequency = 4) represent images of mathematicians associated with musical performance and the image of a rock/pop star like Elvis Presley. The creation of such images can be related to the fact that the participants explored during the course musical DMP as potential mathematical teaching and learning methodology (SCUCUGLIA, 2015).

Three drawings (frequency = 3) reported the mathematician activity linked to a collective/collaborative work, in contrast with the image of mathematicians as uncompanionable, selfish, alone or incapable of interpersonal works. In one drawings (frequency = 1), the image of mathematicians was related with labor market, i.e., their professional role in the realization of activities linked to economy, industrial production (engineering), and technological and computational development.

Finally, one of the images (frequency = 1) reported a photo in which all the students who participated in this research and their classmates appear in classroom. This image is very interesting as it represents the possibility of pre-service teachers to create their own identity as performance mathematicians (GADANIDIS, 2012). In Figure 4, we present some of the pictures created by the participants in relation to the ideal images of mathematicians. The DMP produced on this theme is available at https://youtu.be/oFFVeLeXqjQ.

FIGURE 4 – Students' alternative images of mathematicians.



Source: Research data – students' drawings.

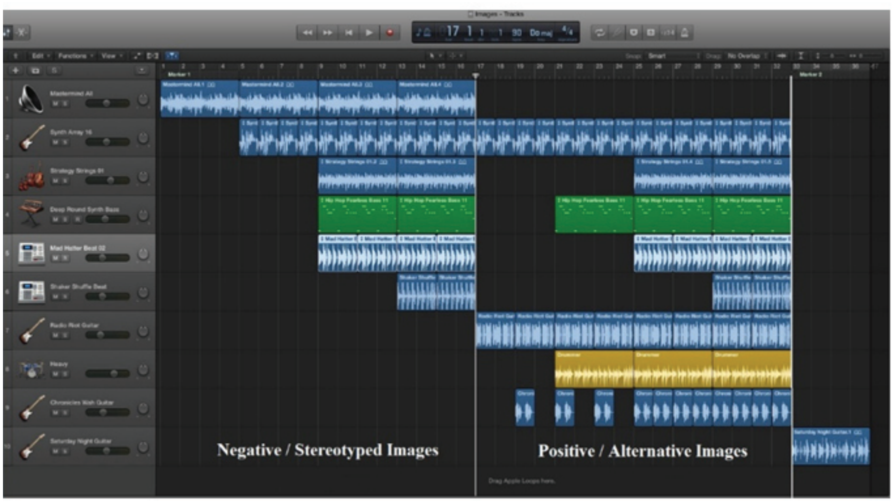
Therefore, within the scope of this research, we consider that the use of arts and digital technologies, especially the production of DMP, offers ways to pre-service teachers (1) deconstruct negative images of mathematicians and (2) elaborate and share alternative images, associated with "good" qualities or characteristics. In this sense, beyond the promotion of pre-service education in environments constructing alternative images of mathematicians – in relation to the stereotypical and negative ones point out to the literature.

Digital mathematical performance

Two DMPs were produced in this study, and both revels the same storyline nature, that is, the same audiovisual-artistic structure. The DMPs intend to express, initially, negative/stereotyped images of mathematics and mathematicians, and, finally, alternative/(des)constructed images. Regarding Scucuglia's (2012) categories on conceptual DMP, the videos present, on the one hand, *vicarious* and *visceral* aspects, because the drawings expressed students' emotional representations on math and mathematicians.

Moreover, in synergy with the music in the video clips, the DMPs may offer *sensations* to the audience because of its intensity on the numbers of images and the visceral quality of the images in synchrony with the musical nature of the created song (see Figure 5: First, negative images are displayed along with a "tense harmony" of the song. Then, alternative images are displayed along with a pleasant harmony of the song).

FIGURE 5 – Screen-captured image of the song produced with Logic Pro software, indicating the nature of the drawings that intend to offer surprise (negative images – tense harmony / positive images – nice harmony).



Source: Research data – screen captured image.

In contrast, both DMPs present lacks in terms of mathematical *sense making* or *reasoning*, that is, rich mathematical ideas are not explored in depth in the DMPs. Students emphasized in their drawings feeling about mathematics and superficial math ideas such as 2 + 2 = 4. Since students did not explored deep-*surprising* mathematical ideas in their drawings, such as infinity and non-Euclidian geometries, the DMPs did not assumed a conceptual nature as theorized by Scucuglia (2012). Therefore, in our research, the production of conceptual DMPs is still a *rare event* (GADANIDIS, 2012).

From the *humans-with-media* perspective (BORBA; VILLARREAL, 2005), the production of DMP tends to offer pedagogic ways to constitute *thinking collectives* and *collective intelligences* (SCUCUGLIA, 2012). We believe that part of the research activities developed these aspects. One the one hand, the creation of the song and the production of videos did not fully involve the participants. On the other hand, the drawings and the storyline of the DMPs were created collectively. Moreover, students expressed their opinions about the artistic digital product conceived and reflected about the pedagogic role of the digital narrative publicly available online. It was process of construction of identities as performance mathematicians (GADANIDIS; BORBA, 2008).

CONCLUSIONS

In terms of teachers' practice, DMP plays a role in the production of pedagogic knowledge (SCUCUGLIA, 2016). In the case of this research, the DMPs played roles in pre-service teacher education. Through the applied questionnaire to the participants, undergraduate students of Education revealed the following conceptions toward the educational dimension of DMPs in their learning process as future teachers:

> *Student A:* When I was a high school student, I felt insecure about math. It was not my favourite subject. When I got into the major in Education, I was worried about "transferring" my insecurity on math to my future students. Exploring the image of mathematics and mathematicians in the course was a turning point in my pedagogic knowledge and view. I know I have to improve my content knowledge on mathematics as a teacher of the subject, but now I know I can enjoy math as I enjoy the arts.
>
> *Student B:* I would highlight the interdisciplinary aspect of the activity we developed. The use of videos and drawings in math is significant for technological and artistic learning for us as future teachers. It was exciting to watch the videos with the drawings we created. The song is also a different way to explore math. We can use these videos in the future or even create our own videos with our students.

Therefore, the research findings offer some evidence about the innovative role of DMP in teacher education, mainly regarding the use of the arts and digital media in practicing mathematics education, (de)constructing images of mathematics and mathematicians. The negative images of mathematics and mathematicians can be significantly improved by changes in mathematics education, especially changes in teacher education activities. Production of DMP by itself is not a sufficient endeavour. In the case of this research we combine creation of DMPs about images of mathematics and mathematicians within a teacher education program. In contrast, Niess and Walker (2010) point out aspects of significance of creation of videos in mathematics teacher education.

> Teacher educators must prepare teachers for guiding students in exploring mathematical concepts and processes in visual ways and use digital video as a tool for communicating their thinking. Teacher educators need to challenge preservice and in-service teachers' beliefs and dispositions about what mathematics is important to learn and how that mathematics needs to be learned, specifically when thinking about digital technologies such as digital videos. Preservice and in-service teachers need opportunities to explore different ways of learning and developing mathematical ideas with digital videos. They need to be challenged to reconsider the mathematics curriculum with respect to what is important to know and be able to do in mathematics. They need to be engaged in using digital videos in exploring mathematics by watching, analyzing, and creating. (NIESS; WALKER, 2010, p.104)

Therefore, we identify limitations in our research results such as the lack in constituting effective thinking collectives in the collaborative process of DMP/ video production. Limitations are also about the conceptual investments towards the conceptuality of the mathematical idea in the DMP. In future research, we must emphasize the exploration of mathematical content in our teaching experiences, highlighting teachers' mathematical thinking in the DMPs. Thus, richness of the mathematical ideas explored in combination with the aesthetics involving reasoning, emotions, and sensations within the artistic-mathematical enterprise must be highlighted in future research activities on DMP and the image of mathematics and mathematicians.

ABBREVIATIONS

DMP: Digital mathematical performance

DMPs: Digital mathematical performances

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