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Creativity and creative thinking: a practical study on the models of Wallas and Hadamard

Criatividade e pensamento criativo: um estudo prático sobre os modelos de Wallas e Hadamard

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Abstract

This article has the objective to present definitions and concepts about creativity and to verify the possible occurrence of the four phases (preparation, incubation, enlightenment and verification) of the creative process, described in the models of Wallas and Hadamard, during an activity of production of student video lessons carried out in two groups of integrated high school students from IFSul, Pelotas Campus. For data collection and analysis, digital portfolios were used to monitor the activities and a questionnaire with open questions to investigate the possible occurrence of the phases. In conclusion, it was possible to verify the occurrence of these four phases, which highlights that creativity is a quality that all individuals possess, to a greater or lesser degree, and that can be developed (encouraged) as knowledge and environment are provided that contribute to its progress.

Keywords: creativity; student video lesson; model of creative thinking; mathematics.

Resumo

Este artigo tem por objetivo apresentar definições e conceitos sobre criatividade e verificar a possível ocorrência das quatro fases (preparação, incubação, iluminação e verificação) do processo criativo, descritas nos modelos de Wallas e Hadamard, durante uma atividade de produção de videoaulas estudantis realizada em duas turmas de alunos do ensino médio integrado do IFSul, campus Pelotas. Para coleta e análise de dados, foram utilizados portifólios digitais como acompanhamento das atividades e questionário com questões abertas para investigação da possível ocorrências das fases. Como conclusão, pôde-se constatar a ocorrência dessas quatro fases, o que destaca que a criatividade é uma qualidade que todos os indivíduos possuem, em maior ou menor grau, e que pode ser desenvolvida (incentivada) à medida que se propicie conhecimento e ambiente que contribuam para seu progresso.

Palavras-chave: criatividade; videoaula estudantil; modelo de pensamento criativo; matemática.

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Introduction: creativity in the production of student mathematics videos

As we work with the production of students' videos as a teaching, learning and assessment method – something that has allowed us to explore the creative potential of our students, providing opportunities for choices, decision-making and remodeling our classes, which until then were mostly expository –, we spent to research concepts and definitions about creativity and creation processes, as we understand that these skills are mobilized by students in their audiovisual productions. Such research led us to know the theories of Graham Wallas and Jacques Hadamard.

In the last semesters, we have added proposals to our teaching practice for the production of student videos of/about mathematics content, aiming at learning that allows students to build it from something they know or learn, imitating or remodeling something they have already learned something that is a reference and/or giving vent to your ideas

Authors such as Oliveira and Alencar (2008) define the creative teacher as a stimulator of creativity, daring and curious, flexible to suggestions, provider of opportunities, protector and encouraging of creative work. Considering these descriptions, it is possible to perceive that many educators can be considered creative, as they seek innovations in their methods; sometimes empirically or due to positive exploratory results, they carry out activities that break the complacency of the expository class.

Creative teachers, encouraged by a creative school, can enhance the creative thinking of their students. Knowing that a student spends most of the day inside an educational institution, this should be the place where imagination is cultivated, where people would be prepared for the world and generate new ideas, new opportunities. "Giving students the chance to solve real problems is an inspiring way to encourage creativity" (Eagleman & Brandt, 2020, p. 235).

Considering that the video production process is ample, as it involves everything from the initial idea of the story to be told to its final exhibition, in this article we will direct a detailed look at the creative development that manifests itself in various stages of its creation. Such a choice will enable us to see that creativity is far beyond what we commonly define as a creative idea, encompassing a whole process consisting of stages/phases that can be encouraged and evaluated by the educator.

This article aims to present definitions and concepts about creativity and to verify the possible occurrence of the four phases (preparation, incubation, enlightenment and verification) of the creative process. Regarding the first part, we present a brief theoretical survey on the meaning and importance of creativity for society and, mainly, for the academic environment; then, we will try to summarize the creative process model developed by Wallas, as well as its subsequent adaptation by Hadamard. Related to the second part, we will present the methodology of a research of the pedagogical intervention type, as well as the results we obtained, which allowed us to map the occurrence of the phases described by Wallas and Hadamard in their models.

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Creativity: exploring concepts

In the various stages involved in the preparation of students' videos – thought-out script, video analysis, scale table, finalized script, recording, editing, cinematographic plans, exhibition, among others (Pereira et al., 2022) –, it is possible to perceive the existence of impulses creative elements that permeate the entire production process. We are not talking here about creativity understood as being the privilege of a few endowed with divine power, nor about a superficial look at a "creative product", but about a process composed of several stages of construction and multiple factors that influence them.

We start from the principle that it is important to provide an environment that stimulates the creation of ideas and that provides adequate techniques for the student's development because every human being, to one degree or another, has creative potential; however, "in most people, the development and expression of these skills have been blocked and inhibited by an environment that encourages fear of ridicule and criticism" (Alencar & Fleith, 2003, p. 9). If we can understand a little about this process and what techniques we can use to stimulate creativity in our students, we will have more opportunities to learn about their skills and to work in an environment that helps them to become more flexible with the opinions of others. and express them more.

In order for us to instigate the spirit of investigation and creativity in our students, we need to have new perspectives on teaching practices that involve creative investigation as a learning factor, so that we can contribute to pedagogical practices that encourage more autonomous learning. Still, aiming to invest in the creative potential of our young students, it is necessary to understand how the creation process takes place. To do so, we will summarize some theories about creativity, each with its own development. In addition, we will present some models that make it possible to evaluate the creative process.

Concepts/Definitions

Until the mid-twentieth century, researchers believed that studies and publications about "creativity" were empirical investigations, difficult to access, and, therefore, little material had been produced on this topic. However, from 1950 onwards, there was a growing interest in investigating the occurrence of the creative process and all the variables that interfere in it, with a particular desire to know the profile of the creative individual and create methods to identify him (Alencar & Fleith, 2003). Since then, many studies have been carried out, of which here we will present concepts, definitions and processes that some scholars have attributed to creativity. Even though there is not total convergence among all researchers, we noticed many points in common and we were able, through exploratory studies, to choose those on which we base our research.

Just as a starting point, let's take a look at the concept of creativity according to the Michaelis[3] online dictionary: "creativity is the quality or state of being creative; ability to

[3] https://michaelis.uol.com.br/moderno-portugues/busca/portugues-brasileiro/criatividade

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create or invent; ingenuity; creative ingenuity". About this first concept we can elaborate some questions: a) Is this quality innate or can it be developed? b) Is the capacity gradual? c) What elements can interfere with this ability? d) When can we guarantee that a product is creative? Let's see if, with the results of some research, we can answer these questions.

According to Gontijo, Carvalho, Fonseca and Farias (2019, p. 19), when we look for the concept of creativity in the history of antiquity, we will find its "origin in a mystical approach that considered it a divine talent or a gift from a spiritual entity, which endowed some individuals with a superior condition of creative power". If so, we could say that creativity is innate only to some human beings and that, therefore, external factors would not interfere with this quality; Nor would it be necessary to guarantee the validity of its creative products, after all, these would be works made by individuals chosen by a god.

Continuing with the research, we found the link between creativity and the state of madness, which, as Faria, Perneta, Teixeira and Félix (2018, p. 22) point out, would be "something that man could not control and that would be impossible to measure". The fact that creativity, in many cases, is spontaneous and irrational, connects it with madness. This connection seems to make more sense when it comes to the creativity of artists, since many of them manifest extremes of mood, thought and behavior, including psychotic behavior (Furtado, 2021).

The fact is that, both in antiquity and in contemporaneity, there are some divergences regarding the concept of creativity. Let's see what some scholars say about the subject, when they treat it devoid of mystical and metaphysical visions.

For Lubart (2007, p. 17), "creativity requires a particular combination of relevant individual factors, such as intellectual abilities and personality traits, in addition to the environmental context". In his research on the relationship between Yin-Yang and creativity, Bucho (2016, p. 06) highlights the need to value creativity, which he considers the greatest human potential, and corroborates with Lubart, when he states: "the context sociocultural [...] functioning as an inhibitor of creativity or as a facilitator of its development". Both researchers refer to the influence of the environmental/sociocultural context on the development of creativity in individuals, as they believe it to be a quality that can be developed.

As previously mentioned, although there is no consensus to define creativity, many researchers defend the importance of environments that provide creative experiences and, in the case of the school environment, emphasize the relevance of the teacher's role as a supporter of creative acts. It is necessary to consider that "there are numerous strategies that lead to the creation of an environment conducive to creativity, an environment that gives the student chances to have experiences and living creativity, however, the attitude of the teacher in the classroom is fundamental for this" (Oliveira & Alencar, 2008, p. 300). We believe that creative teachers are encouraging sources for students to develop their creativity, seeking, through innovative ideas, to create environments conducive to this end. In this perspective that environmental conditions can favor or inhibit creative production, Alencar and Fleith

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(2003, p. 16) consider creativity as a "sociocultural process and not just an individual phenomenon", which answers the question about the elements (factors) that can interfere in the development of creativity.

Another factor that draws our attention is the possibility of creativity providing interdisciplinary connections, which does not mean the need for in-depth knowledge in each area involved, but a necessary investigation to understand the context of what is being investigated (Gardner, 1996).

The greater the number of connections with different lines of reasoning, the greater the chances of success in coping with the situation experienced. For this to happen, we need to feed the brain with information that belongs not only to our area of expertise or the one with which we have the greatest affinity, but at least from related areas, which can provide complementary knowledge to that more specific one. Alencar and Fleith (2003), in their studies on creativity, comment on the analysis of people's behavior, stating that great creative contributions to society, with original ideas or products - it should be noted that the reference to creative "products" is related both material objects (works of art, domestic utensils, clothing, machinery, etc.) as well as immaterial objects (poems, songs, theorem demonstrations, etc.) or existing techniques in the area in which they worked, in addition to having some knowledge in related areas. Bringing this analysis to the classroom, in the creative process involved in the production of student mathematics videos, students who have some knowledge of digital technologies, mathematics and related areas, it will have a greater chance of making a creative video, in addition to some knowledge (artistic, literary, musical, historical, etc) of the world that surrounds him, in order to establish richer contextual relationships in his narrative, being of fundamental importance to have an environment (space and teacher's guidance) that allows him to acquire and practice this knowledge.

There are still researchers, such as Lubart, who claim that creativity constitutes intelligence, which others disagree saying it is an independent element of intelligence. Ellis Paul Torrance, known as the father of creativity research, was challenged by a psychologist and human intelligence researcher, Joy Paul Guilford, to investigate creativity, which was a little-known topic until the mid-twentieth century, content of great importance for the development of mankind, as Guilford believed. Torrance defended the idea that "all individuals have creative potential, recognizing their different forms of expression (verbal, figural, corporal, among others)" (Wechsler & Nakano, 2020, p. 31) and saw creativity as a process that could be changed or developed during the life of the human being, in all phases of its development and in the most varied environments.

Some research gave rise to tests that allow measuring creativity, seeking to analyze how the construction of an idea/product occurs. One of the first tests was developed by Torrance and called Minnesota Tests of Creative Thinking, in which four dimensions are evaluated through some activities developed to measure creativity. The dimensions assessed are: a) Sensitivity to problems: perception of the existence of a problem and questions about it; b) Ideation fluency: ability to think of several possible solutions to solve the problem; c)

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Flexibility: thinking in action in the search for alternative solutions; d) Originality: production of unconventional responses (Wechsler & Nakano, 2020).

With regard to originality – new ideas, re-elaboration or improvement of existing products or ideas – we will find this dimension cited in several definitions of creativity, with the creative product having to be unique and original, autonomous and directed towards the production of a new form. The issue of relevance is also often cited – a product is considered creative if, in addition to being new (or original), it is relevant (useful/important) in the medium in which it is being presented (Alencar & Fleith, 2003).

There are researchers who describe the creative process in stages. Graham Wallas, an English psychologist who was born in 1858, "described the creative process in four stages, some occurring at the level of conscious functions and others arising at the core of unconscious processes: the preparation phase, the incubation phase, the enlightenment phase, and the verification phase" (Gontijo et al., 2019, p. 20).

Considering that the creative process takes place within an integrated context of stages, some contemporary researchers approach the phenomenon of creativity in a systemic model (derived from several factors), and not in a fragmented way as approached in the classic models. Gontijo et al. (2019, p. 26–36), investigating creativity in mathematics, presented Sternberg and Lubart's theory of investment, Amabile's componential model and Csikszentmihalyi's systems perspective, from which we concluded two points of convergence: i) address the phenomenon of creativity as being derived from the interrelation between the individual, knowledge and the environment; ii) point out that a product only receives the creative label when it has social significance, otherwise it may be rejected and not validated.

We also noticed that, for Lubart (2007), intuition is an important part of the creative process, as it guides the initial ideas, pointing to those that seem to be most promising, and also because it is a more individualized way of thinking than the logical way. Amabile (at Gontijo et al., 2019, p. 31) "considers that creativity is the ability to propose products and responses that are new, appropriate, useful, correct or of value for a given task, considering that this task must be heuristic in nature and not algorithmic", that is, creative ideas arise in the unconscious, when the brain "at rest" makes the connections of stored knowledge.

Now, as an attempt to answer the questions triggered from the definition found in the Michaelis dictionary and the referenced studies, we will summarize as follows: **Creativity is a quality that everyone has, to a greater or lesser degree, and that can be developed (encouraged) – in a communion between conscious and unconscious – as knowledge and environment are provided that contribute to its progress, the final product being considered creative when it has importance in the environment (where and for whom) in which it was developed.**

Considering the importance of the role of the unconscious in the unfolding of the creative process, we are going to address the model that divides this process into four stages, two of which are developed in the conscious region and the other two in the unconscious

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region, where enlightenment takes place.

The Graham Wallas Model

It is not uncommon for the solution to a problem that afflicts us to come up at unexpected times; that a forgotten name is remembered when we are not thinking about it; that an idea is created in a moment of "brain relaxation".

For many researchers, creativity is the result of both the conscious and unconscious work of the thinking being. It manifests itself in ideas that pop up when the brain is not consciously working on a particular problem, but which need logical, conscious thought to put it to the test. Graham Wallas used this line of thought to define the four phases of his model of the creation process. It is possible that this current of thought originated from the studies of Jules Henri Poincaré (1854-1912), a French mathematician, physicist and philosopher who, at the beginning of the 20th century, referred to three phases of the creative process, very similar to those described by Wallas, being the first

> [...] a **reflective** phase of research and calculation (preparation phase); the second would be an unconscious phase of **maturation** of ideas, from which a synthesis chosen by a sort of deep aesthetic sensitivity would emerge, which would correspond to the enlightenment phase, also highlighting the final phase of idea **verification** (Alencar & Fleith, 2003, p. 43, our highlights).

Hermann von Helmholtz (1821-1894), a German mathematician, physician and physicist in the same period, also described the creative process in three phases, which he called: **saturation**, which refers to the reflective phase, the moment in which data are gathered for the formation of ideas; **incubation**, referring to the maturation of ideas, when they are combined in the unconscious; and **enlightenment**, when there are moments of sudden responses (Alencar & Fleith, 2003).

With this line of reasoning, psychologist Wallas developed, in 1926, his model of creative thinking, dividing the creation process into four stages. His model and the description of each stage are contained in his work, *The art of thought*, from which we make some considerations. Of the four stages described, some of them are worked on in the person's conscious level process and others in the unconscious level process. They are: **preparation** phase, **incubation** phase, **enlightenment** phase and **verification** phase. Let's see what constitutes each of the phases:

i) Preparation phase: in this phase, of activity at a conscious level, the individual becomes aware of the entire problem; analyzes it; investigates its possible aspects; verifies that it has the tools to proceed with the solution; experiment; organizes to create; searches for initial information.

ii) Incubation phase: this is a phase, at the level of unconsciousness, in which the individual internalizes the problem; even if the person tries to disconnect from it, performing different activities, the brain continues working, making associations and seeking relationships with the knowledge already stored in the unconscious.

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iii) Enlightenment phase: of all the ideas and relationships obtained during the incubation phase, one should stand out bringing light to the problem; it's that moment we call insight, in which the solution suddenly appears and everything seems to make sense; it is a reward phase for all the effort invested, which develops at an unconscious level.

iv) Verification phase: this is the time to test the functionality of the idea, raising its possible problems and trying to correct them; during correction or improvement, it may be necessary to go through the previous phases; it is a phase that takes place at a conscious level of reasoning so that the product of creation can be analyzed, verified and validated (or not), opting to improve it or abandon it.

By analyzing the stages described by Wallas and relating them to the theories presented, we could see that, for the preparation phase, it is essential to take into account the individual as a being who has his own background of knowledge, experiences, mistakes and successes, with a life trajectory that will provide (or not) the possibility of advancing in his creation process. The greater the knowledge in a given area – not only the one that is directly related to the idea in the creative process, but also those that serve as support to compose the solution –, the greater the possibilities for the brain to seek relationships and make associations of the idea with other areas. the knowledge stored in the unconscious, thus passing through the incubation and enlightenment phases (Haetinger, 2008). With regard to the environment, we can relate it to the verification of the product derived from the creative process – evaluated within a certain social context (Lubart, 2007) –, as well as the space in which the process takes place, which is of fundamental importance with regard to encouraging creation (resources and encouraging teachers). Although there is a current of thought that the process is only complete if verified and accepted in a certain social environment (Alencar & Fleith, 2003), there were cases in which the acceptance and recognition of the creative idea/product(s) only took place years after the author's death: Gontijo et al. (2019) cite, as an example, the case of works by Leonardo Da Vinci and Vincent van Gogh, which were posthumously recognized.

In 1954, mathematician Jacques Hadamard described the four phases of the creative process in Wallas' model, relating them to creativity in mathematics, a topic that we address in the next section.

Creativity in Mathematics

The French mathematician Jacques Hadamard (1865-1963) studied the psychology of invention in mathematics, seeking to understand how the conscious and unconscious functions in discovery processes. Strongly inspired by Poincaré's studies, he was able to verify the agreement between his theories and events in his private life, thus coming to believe that the knowledge accumulated in our minds intertwines and generates countless combinations (useful and useless) and that the region of “marginal awareness” (a region that compares to peripheral vision, out of central focus, but noticeable when something catches the attention) selects and examines useful combinations that will be of service in a discovery

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process. It is worth mentioning here that Hadamard (2009) differentiates enlightenment from discovery: the first appears suddenly and unexpectedly; the second stems from a new work, from other attempts

After reflections on the theories of Poincaré and many other researchers of the conscious and unconscious processes, with regard to discoveries and creativity, we outline a synthesis of what Hadamard says about the four phases of the creative process, described by Wallas:

i) Preparation phase: it is a phase resulting from intense and perhaps long conscious work; a research phase, to look for possible ways to solve a certain problem; it is a phase that precedes incubation and enlightenment.

"The act of studying an issue consists of mobilizing ideas; not just any ideas, but those from which we can reasonably expect the desired solution. This work may not have an immediate result" (Hadamard, 2009, p. 64). With many ideas derived from different research, some collide and combine, and "in these new combinations, in these indirect results of our initial conscious work, we find the possibilities of an inspiration that seems spontaneous" (Hadamard, 2009, p. 65). It is in the hard work of the conscious that directions emerge for the unconscious to carry out the appropriate combinations of ideas, in an attempt to find answers to an initial problem.

Still on this phase, Hadamard (2009) pays attention to the fact that we often move towards a special and absolute direction, so that we fail to perceive the ideas that are "out of line", and it is possible that the answer to what we are looking for may be before our eyes, but on a different path from the one we obstinately chose to follow.

ii) Incubation phase: in this phase, the unconscious seeks to make combinations/connections between the ideas obtained in the preparation phase, in order to find an answer or a path that indicates a possible result.

> It is evident that invention or discovery, in mathematics as in other areas, occurs through combinations of ideas. Now there are an extraordinarily large number of such combinations, almost all of which are of no interest. Very few can be fruitful. What are those that our spirit – I mean our conscious spirit – perceives? Only those that are fecund or, exceptionally, those that could become fecund (Hadamard, 2009, p. 45).

These ideas, according to the researcher, are adrift in the marginal consciousness, the fertile ones being perceived in the form of a flash (enlightenment).

iii) Enlightenment phase: when studying this phase, Hadamard came across some theories, among them: the **hypothesis of rest** and the **hypothesis of forgetting**. Both are based on the fact that the enlightenment phase proceeds from the incubation phase. In the first hypothesis, a rested brain would be more able to combine the best ideas and make the necessary connections between them; in the second, the incubation would allow the rest to allow the brain to get out of the way of difficulties and confusing possibilities, a hypothesis proposed by Poincaré.

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Hadamard agrees with the idea that, some time after the preparatory work (months), the spirit will be fresh or open, forgetting frustrated attempts, providing the possibility of discovery. He states that, in this case, it is a "discovery" and not an "enlightenment", since the solution does not appear unexpectedly. And taking as examples cases that occurred and narrated by Poincaré, and with himself, Hadarmad (2009, p. 52) states that "'enlightenment' appears suddenly, without perceptible effort".

iv) Verification phase: it is a phase prior to the ending; this is the moment when you need to take a fresh look at the results obtained, as if you were checking someone else's work and analyzing all possible errors. Very often, this phase is reached and it is realized that mistakes made in the previous phases made the work unfinished, requiring corrections.

Hadamard draws attention to what he calls "intermediate results", which are results obtained during a study, even if they are not the final ones, however they have the potential to be linked to new research. "When such an articulation is achieved, quite analogous to a railroad fork, the new direction in which the research will proceed has to be decided" (Hadamard, 2009, p. 81). This decision is processed in the conscious. In the case of mathematics, these "intermediate results" are used systematically with regard to theorem demonstrations, for example. "Each result, each solution that he (the mathematician) knows is the source of new problems" (Hadamard, 2009, p. 152).

We noticed that there are no differences of thought between the phases described by Wallas and Hadamard's observations, just the fact that the last directed his attention to events in his life as a mathematical researcher.

Many researchers use methods that intend to measure the degree of creativity of the individual, an activity that is not consensual for at least two reasons: the first concerns the validity of creativity tests, which is, if it is something that can even be measured and what would be the extent of these measures; the second addresses the need for training teachers and students so that they can become more effective in assessing (and possibly measuring) creativity (Alencar & Fleith, 2003).

In our studies, we do not intend to measure students' creativity, but to use the creative process as a teaching, learning and evaluation method. In this way, we saw in the phases described by Wallas and Hadamard a way to guide our students in their creative processes, helping in the construction of knowledge and enabling the exercise and practice of ideas that involve various skills, especially those that would not have a place in a traditional class, such as: musical and/or poetic compositions, artistic interpretations, handcraft work, etc. The activities we developed, which allowed us to verify these phases, are presented in the subsequent section.

An analysis of creative thinking in student video production

Method description

In this item, we describe the results of an experience in which we empirically

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explored the production process of student videos as a pedagogical proposal for teaching, learning and evaluation. In this one, as we had already studied the stages of the creative process, we proposed to scrutinize them, in order to understand how the development of creativity that permeates the production of video classes takes place.

This practice was carried out in two classes of integrated technical education[4] at IFSul Campus Pelotas, from which the first author of this article was the main teacher. The activity took place over twelve weeks of the first semester of 2021, in the remote model, at the time composed of synchronous and asynchronous classes.

As one of the evaluative activities of the Mathematics discipline, students should produce a video lesson that explored some topic of the content scheduled for the school period: functions (exponential and logarithmic) and progressions (arithmetic and geometric).

At the first meeting, we provide some guidance on video production and, at previously scheduled times, we offer technical support on recording and editing. Throughout the entire process, we remained available to answer questions that arose during the execution of the activity.

The synchronous classes took place on the Google Meet video conferencing platform, and were composed, with regard to the studied contents, of tasks and study materials; regarding the preparation of the videos, there were moments in these classes when we presented and explained to the students the relevance of the free and informed consent form for the use of data, among other documents, which were hosted in a Virtual Learning Environment – VLE, in Portuguese: AVA –, IFSUL own platform.

To monitor the production activity of the videos, we request a weekly “activity report”. This report was analyzed and returned to the students with notes and corrections, when necessary. To send the reports, “tasks” were created in the VLE/AVA, with the following descriptions: i) write the initial idea of the script that would originate the video ii) deliver the video script; iii) describe recording technique; iii) post video preview; iv) post post editing video; v) post finished video.

It is important to note that, after posting each task, we returned the reports to the students with some observations/guidelines and, when necessary, we scheduled an online meeting to discuss the progress of the work. In addition to the VLE/AVA, some students used the e-mail resource to send questions, which were answered within the same week.

In order to assess whether the four stages of Wallas' creative thinking model were verified during the video production process (preparation, incubation, enlightenment and verification), we prepared a questionnaire with open questions, in the expectation that the students' individual responses could lead us to understand whether the phases had, in fact, occurred. This questionnaire was prepared within the VLE/AVA, using a specific tool for this purpose. In the elaborated questions, we sought to investigate whether the students: a)

[4] Courses in which high school is combined with technical training.

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verified whether they had resources (material and intellectual) to carry out their ideas; b) thought about giving up the initial idea and looking for a new one; c) during the development of activities they had some kind of insight; d) considered their works as original/new; e) checked the verification of their work; f) after the ending of the video, they still believed that there were flaws to be corrected.

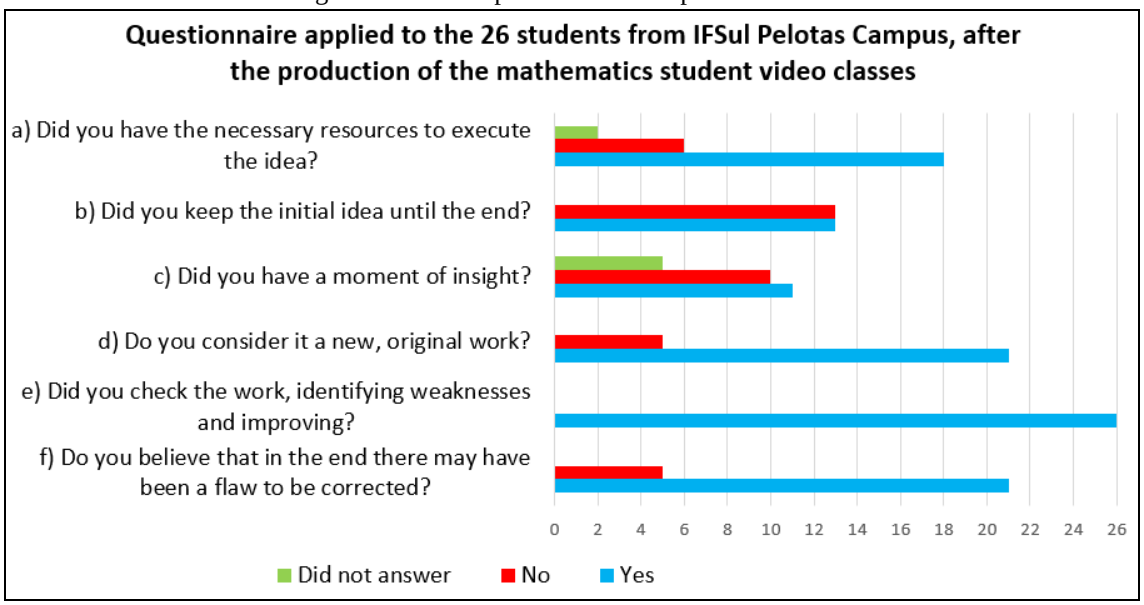
The research methodology we used is characterized as being a **pedagogical intervention** because it is an investigation that involves "the planning and implementation of interferences (changes, innovations) – intended to produce advances, improvements, in the learning processes of the subjects who participate in them – and the subsequent evaluation of the effects of these interferences" (Damiani et al., 2013, p. 58). These same authors compare pedagogical intervention research with experiments, in the sense that both experiment with new things, but experiments are governed by quantitative research, while pedagogical interventions are governed by qualitative research.

Results obtained

Although the questionnaire applied to investigate the possible occurrence of the four stages of Wallas's creative thinking model was elaborated with open questions, it was possible to extract an affirmative or negative answer from each question, since, after answering "yes" or "no", the students should elaborate on their answers.

As a way of representing the quantified answers given to the investigative questions, we created a bar graph and presented it in Figure 1.

Figure 1 – Bar Graph to illustrate experiment results



Source: Prepared by the authors

The answers to items "a" and "b" led us to conclude that the preparation and incubation phases occurred; and the answers to items "c", "d", "e" and "f", led us to conclude that the enlightenment and verification phases had occurred.

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Altogether, twenty-four videos were produced, made in trios, pairs or individually. We obtained twenty-six completed questionnaires, because two students chose to answer it individually, even though their group had already done so. Some responses were vague, not allowing us a clear interpretation and, therefore, we left them as "did not respond".

According to our analyzes and interpretations of questions "a" and "b", we noticed that all students went through the preparation phase, although in different ways: some perceived the lack of resources to continue with their projects, reaching the point of changing their initial ideas; others went in search of resources; and there was a group that, for different reasons, chose to change the initial idea.

In this phase, the preparation phase, they analyzed the resources they had: mathematical knowledge acquired inside and outside the school space and technological tools for practical development. In only two responses given, we could not conclude whether the preparation phase was contemplated, but we believe so, due to the progress of the other phases, considering that the task of creating the videos was completed. We could also see, from some responses, that there was a concern to relate the mathematical knowledge of the content under study with the particular experiences of each one, which facilitates the incubation period, making it easier to make associations and relations of the knowledge stored in the unconscious with the idea that one wants to put into practice, corroborating the thinking of Piaget and Gardner (1996), among others.

To exemplify, we transcribe part of a report in which one of the students reports the conversation he had with his colleague: *Two days before the actual start of work, I got on a call with a group partner and asked: "What do you have in mind for the work?" And the same replied with great happiness that he wanted a musical. I said without thinking twice, "Perfect".*

The students in question produced a music video about the propagation rate of the COVID-19 virus, relating it to a geometric progression. For it, they composed lyrics and music, played and sang the definitions of geometric progression, with the theme of "social distancing"[5].

As for question "c", which investigates whether or not there was a moment of *insight* – a term that had its meaning clarified for the students –, the class was divided between those who considered having had a moment of "enlightenment" and those others who said they had an idea linked to another, in a simple and continuous way, what Hadamard (2009) defines as "discovery". We realized, when analyzing all the responses, that most students started from a subject in which they had prior knowledge, just making connections with the content being studied. In the meantime, a group of students responded to the question by saying that the solutions were emerging in the development of the work, without a sudden answer to their questions, while the other group claimed to have been contemplated with an enlightenment

[5] Video link composed by students and supervised to the V Festival of Digital Videos and Mathematics Education: https://youtu.be/j77sbGa3Wyw

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moment. The incubation process is inserted in this period between preparation and enlightenment, as a preparation both for the moment of *insight* and for the development and completion of the creative work.

When asked, in "e", about verifying their work, that is, about the finished video, all were unanimous in stating that they had made numerous corrections and changes throughout the school term and, also, that they had asked family members and/or colleagues to watch their videos and report possible problems.

With the last three questions ("d", "e" and "f"), we were interested in knowing if the students had thought (created) something new or if they had been inspired by some work already published. As we could see, a few said they were inspired by existing materials, but the vast majority believe there was originality in the way they presented the chosen theme.

Final considerations

The studies on the steps involved in the production of a student mathematics video, with regard to the creative process, bring elements that require special attention from our eyes to the cognitive process involved in this proposed activity.

In this cognitive process are the "psychological processes involved with knowledge, understanding, perception and learning" (Alencar & Fleith, 2003, p. 26). What we could understand from the study on the development of creativity is that all people, without exception, have possibilities to create. Creativity is not a divine gift or a product of chance, but a capacity that we possess to a certain degree and that can be developed if stimulated in a favorable environment and with convenient stimuli. Among the stimuli, we can mention the creation of something new, whether out of necessity, pleasure or even obligation, as well as developing new ideas, remaking, rewriting, recreating.

When we were willing to experiment with the student video production method during our academic activities, we realized that it favored the development of creativity when we were faced with the variety of narratives, with the multiplicity of skills involved, with the exchange of knowledge between student and teacher and with the stages of creating the video. We noticed, throughout this course, creative factors that can be explored in the learning process. With these ideas in mind, we ventured into studies involving the method of producing student video lessons, taking it as a process capable of encouraging the development of student creativity.

We believe that the intervention carried out and the results obtained from it make it possible to reflect on the teaching activity, draw attention to the importance of creative investigation as a learning factor and encourage the teacher to be more creative in order to provide the necessary environment and help to the student who seeks to develop his/her creativity.

In their book on creativity, Alencar and Fleith (2003) comment on some factors related to the intellectual operations present in the creative process: **fluency skills**, **flexibility**

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and **originality**. When we analyzed the whole process of creating a student video, we strongly noticed the presence of these factors. Fluency – which refers to the ideas that the individual has to start acting on their problem – can be perceived (and even measured) as the student dialogues with the teacher and exchanges opinions about their initial ideas; flexibility – which implies breaking with a pattern of thought, viewing the problem from different perspectives and freeing the mind from a rigidity that can imprison it in fruitless paths – can be evaluated as the student has the ability to change the direction of thought, seeking new ways of thinking. strategies for solving his/her problem, when the initial ideas are insufficient; finally, originality – characterized by unusual solutions, new or innovative results or transformations – can be verified when inserting new elements in the narrative, telling cohesive and effective stories to develop the desired mathematical reasoning, among others.

Considering the stages described in the Wallas and Hadamard models – preparation, incubation, enlightenment and verification –, the teacher involved in the creation process will be able to perceive them and help in the development of those that happen at a conscious level, which are preparation and verification. With the exchange of knowledge and direction for further studies, the teacher can help in the preparation phase for the emergence of the creative product. The student, when well assisted, will be able to "feed" his consciousness with the information that will be combined and related in the unconscious (or marginal consciousness, as defined by Hadamard (2009)), providing possible moments of enlightenment. Regarding the verification phase, we consider it to be of great importance in the learning process, and it can be carried out in the large group of the classroom, so that everyone can participate and contribute to the improvement and/or reformulation of some concept that has not been once well understood, indicate programs or tools that can help in demonstrating the problem and, thus, solve the doubts and difficulties that may have gone through the previous processes, actions that would allow the student to resume the previous phases and adjust them to the proposed problem.

Analyzing the creative process, we were able to perceive that, within a methodological proposal of creative work in the educational context, the educator can provide the student with: autonomy to take their own initiatives, to perceive and combine the stored information, acquiring self-confidence in his/her task; socialization of ideas and results, favoring the creation of affective bonds between peers; new looks at a problem, facilitating the resolution of future challenges and encouraging to perform more difficult tasks; satisfaction and pleasure with the advancement of knowledge and results under construction; help to know how to deal with failure, encouraging new attempts; appreciation of his/her work.

After all this exposition, we understand that there are many justifications for considering creativity as an important part of the teaching, learning and constant evaluation process. We had the opportunity to explore the method of producing student video classes from the perspective of creativity studies and to follow the creative process in it, according to the phases described by Wallas and Hadamard. In the end, we were able to refine our

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perceptions of this process, which allowed us to reflect further and new ideas for application. Hadamard, as a mathematical researcher, provided us with reflections more focused on creative processes in our area of knowledge, helping us to think of it as an integral part of the production method of student mathematics videos. After all, we teachers are also eternal learners: just as we were able to verify the stages of the creative process in our students, they also manifested themselves in our teaching work.

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