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Dragons, Monsters, Emotions, Cavemen and Kuhn's Epistemology: Scientific Revolutions in Films

Marcos Vinícius de Melo Oliveira[a]
Augusto Francener[b]
Cristiano Hintze[a]

[a] Prefeitura de São Paulo, Secretaria Municipal de Educação, São Paulo, SP, Brasil
[b] Prefeitura de Goiana, Secretaria de Educação e Inovação, Goiana, PE, Brasil

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ABSTRACT

Background: There have been many discussions on the importance of teaching philosophy of science in schools, and the need of a teaching focused on the science process, seeking to remedy deformed views that distance children from scientific life. Kuhn is undoubtedly the science philosopher most debated in history and his work "The Structure of Scientific Revolutions" has significant potential to construct proper views of the scientist in primary education. Films are important pedagogic tools to transmit concepts and ideas in a rich and engaging way. **Objectives**: The present work identified the presence of Kuhn ideas in four animated films and the competences of science procedures in their characters. **Design**: We selected the films "How to Train Your Dragon", "The Croods", "Inside Out" and "Monsters, Inc.". Within those, we seek for paradigms, paradigm shifts, scientific revolutions, and the competences for scientific investigation on the characters. **Setting and Participants**: This is a theoretical analysis, and therefore does not have participants. The materials used were only bibliographic sources**. Data collection and analysis**: We used ten scientific competences and made a philosophical reflection of Kuhn's theory in the films. **Results**: The analysis reveals the occurrence of normal science, recognized anomalies, extraordinary science and break of paradigms in all those films. In addition, we identified the competences of science procedures of the characters. **Conclusions**: The films make an artistic representation of situations where Kuhn concepts and the scientific competences can be taught in a clear and significant way.

Keywords: Animated movies, Scientific Competences, Paradigm shift, Philosophy of Science, Thomas Kuhn.

Dragões, monstros, emoções, homens das cavernas e a Filosofia de Kuhn: revoluções científicas nos filmes

RESUMO

Contexto: Muito se tem discutido sobre a importância de se ensinar sobre a filosofia da ciência nas escolas, e da necessidade de um ensino com enfoque no processo da ciência, buscando

Corresponding author: Marcus Vinícius de Melo Oliveira. Email: oliveira_mvm@hotmail.com

sanar visões deformadas que afastam as crianças da vida científica. Kuhn sem dúvida é o filósofo da ciência mais debatido da história e compreender sua obra "A Estrutura das revoluções científicas", tem um potencial significativo para construir visões apropriadas do cientista no ensino básico. Os filmes são importantes ferramentas pedagógicas paras se transmitir conceitos e ideias, de forma rica e envolvente. **Objetivos:** Este trabalho identificou a presença das ideias de Kuhn em quatro filmes de animação e os procedimentos de competências científicas em seus personagens. **Design:** Selecionamos os filmes: "Como Treinar Seu Dragão", Os Croods", "Divertidamente" e "Monstros, S.A.". Neles procuramos por paradigmas, mudanças de paradigma, revoluções científicas e as competências para investigação científica nos personagens. **Ambiente e participantes:** Esta é uma análise teórica, e, portanto, não conta com participantes. Os materiais utilizados foram apenas de fontes bibliográficas. **Coleta e análise de dados:** Usamos dez competências científicas e fizemos uma reflexão filosófica da teoria de Kuhn nos filmes. **Resultados:** A análise revelou a ocorrência da ciência normal, anomalias reconhecidas, ciência extraordinária e a quebra de paradigmas em todos esses filmes. Além disso, encontramos quase todas as competências científicas nos personagens. **Conclusão:** Os filmes possuem uma representação artística de situações em que os conceitos de Kuhn e as competências científicas podem ser ensinados de forma clara e significativa.

Palavras-chave: Competências Científicas, Filme de Animação, Filosofia da Ciência, Mudança de Paradigma, Thomas Kuhn.

INTRODUCTION

The importance of Thomas Samuel Kuhn and his work is undeniable to understand how science works. His view of normal science, recognized anomalies, paradigms and scientific revolutions reveals aspects of fundamental sciences to guide students in a consistent scientific literacy.

Moreover, some studies reveal the double face of science (product and process) (e.g. Furman, 2011) and that a disproportionate emphasis on its Products has a negative impact on the view of science students can build, increasing what Gil-Perez (2005) points out as distorted views of sciences and technologies.

Seeking sources where the work of scientists and their main skills are presented in a way that will not feed an impoverished view of their work is necessary to provide democratization and more engagement of students with science.

Films are a potential source of sensitization and clarification of scientific concepts and views in a significant way, accessible to Primary Education students. Given this, the aim of the present work is the analysis of films for science teaching with focus on the process in the light of Thomas Kuhn philosophy.

Kuhn's epistemology and the structure of scientific revolutions

The philosophy of science is a discipline in which the concepts and theories of the sciences are analyzed and clarified. Besides that, it is an exposition of the presuppositions and predispositions of scientists. Based on these presuppositions, point out the nature is

not capricious, and that there exist in nature regularities of sufficiently low complexities to be accessible to the investigator (Losee, 2001)

Including philosophy of science in classrooms can contribute to a wider understanding of scientific contents, generating a better understanding of the science structure and its place for the reading of the world (Matthews, 2009). And when we talk about philosophy of science, we can't avoid mentioning the physicist Thomas Samuel Kuhn (1922-1996).

He was one of the most influential philosophers of Science in the last century, and his book "The Structure of Scientific Revolutions" became one of the great books in history. In the work we find the word *paradigm* followed by the term *paradigm shift*, which became usual after its publication (Hacking, 2013).

Moreover, Kuhn used the term 'normal science' which, in the author words: It is the research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice (Kuhn, 2013).

For him, normal science goes hand in hand with paradigms (Kuhn, 2013). That is, we can understand normal science as the set of scientific activities based on a paradigm as aegis. According to Mendonça (2012), the paradigms bring consensus, ceasing debates on methodological, epistemological, and ontological orders. Then, scientists can spend their time on further specific issues.

Within their own normal science, whatever is the science universe, scientists seek, among other things, to harmonize possible ambiguities in its paradigm. That is why some scientists work within a paradigm, committed to it in an almost dogmatic way. And scientists are not always looking for new theories and are often intolerant to those invented by others (Kuhn, 2013; Barber, 1961).

For Kuhn, while seeking to improve the paradigm, anomalies (problems not provided in the current theory) end up becoming increasingly more evident. The paradigm goes into crisis and leaves room to another one, demanding the abandonment of the old paradigm, since the two are incompatible (which Kuhn calls incommensurability).

The new paradigm can then explain and predict anomalies and old predictions as well. And so, we have the transition to the new paradigm (paradigm shift); a process Kuhn calls scientific revolution (Kuhn, 2013; Ostermann, 1993). The revolution period generates a shift in the conception of the world, and the perception the scientist has of his environment must be reeducated (Kuhn, 2013).

With "The Structure of Scientific Revolutions" Kuhn could propose a theory that dominated the field of philosophy of science, as well explained:

> Without taking the risk of exaggeration, Kuhn became the most influential person, or at least the most debated person, in the Anglophone philosophy of science in the second half of the 20th century. The large amount of works about him that,

> in the last years, keeps on being published is a strong indication of the topicality of his ideas, as well as the lasting influence of his work. His book The Structure of Scientific Revolutions (1978 [1962]) is the greatest best-seller in the history of epistemology, having caused a real "revolution" in philosophical issues referring to science. (Mendonça, 2012, our translation)

As Kuhn's epistemology is so important to understand how science is developed, its process as a whole, it must be taught in classrooms:

> Kuhn's ideas represent an important reference for the work in classroom. The view of science transmitted in classrooms and textbooks, and the teaching strategies used can be based on Kuhn's model of scientific development. (Ostermann, 1996, our translation)

The need to teach science with focus on the process

Considering our experience as teachers of Science in elementary school, it is common to notice the habit of teaching with focus on science as product, that is, on the "ready" concepts of science, as already observed by Sitko (2020). Because there are many concepts to be worked on, we can make the mistake of focusing only on their transmission, since we have a considerable curriculum load to be fulfilled in the school year.

In his work, Furman (2011) represents Science as a double side coin, one of them is the "Science as product", and the one most privileged in schools, and the other is the "Science as process". The author states that the process that enabled us to discover what we know is more important than what we know and, ironically, is the one that we rarely find in schools.

While understanding Science as a product alone, it is not clear for the students the contexts where the scientific concepts were conceived. The problems and questioning that guided the whole investigative practice are also omitted, the dilemmas faced by scientists and their trials and errors are not presented and, worse of all, the scientific doing becomes something inaccessible or simply intangible. We also understand that teaching with focus on the product has a significant impact on the deformed view of science (Sitko, 2020).

As well represented:

> It is sure that if someone (the society, for example) gives primacy to the useful aspects of the scientific activity at the expense of its intellectual acquisitions, we would no longer have science, or any perspective of real progress in our understanding of the world. (Paty, 1999, our translation).

It is essential for Science democratization and for the development of scientific literacy in schools that scientists are presented as they really are: human. They have their insecurities, doubts, many times they face difficulties to learn something, get confused, are inserted in a culture that influences their views of the world, that is, they are common persons.

This perception that the scientist is a "common" person makes of science something possible and also desirable (Mattews, 2015). And not only that, it also reveals that in many daily situations we act like scientists without being aware of it. Common persons, reflecting about common problems, having simple essential attitudes of a scientist, can create extraordinary things for the single fact that they stopped to think more deeply over something until they can find the missing piece.

As my genetics professor, Dr. Alexandre Siqueira, used to say: "The distance between you and a Nobel Prize is one experiment" (personal communication).

However, what a scientist does is not clear for our students. The knowledge of what is practiced is what arouses interest for people to want to practice as well. By analogy, initially, it is the knowledge of what a football player does that makes football something so much practiced. Today, what many science teachers are doing is "showing the result of the match" rather than "the match".

> Thus, in addition to providing more meaning to the content at issue, it is believed that the use of Science History and Philosophy in the teaching of Science can provide humanization to the scientific work, bringing Science closer to the student, showing that scientists are common persons. That way, it is believed that, based on historical approaches, the student will be more interested in studying science, and will also understand more easily how scientific knowledge is produced". (Mattews, 2015 apud Sitko, 2020, our translation)

How to clearly and significantly demonstrate the procedures of science investigation by common people in a given context, and historically, making clear the potential impact on paradigm shifts and, therefore, on scientific revolutions?

The importance of using films in the teaching of Science

As already demonstrated, students' view of science is usually much distorted. There is a distance, in the student mind, between science and technology and the way scientific and technological knowledge is built (Gil-Peréz et al., 2005). The summit of this distance is the representation of the scientist as a character: bold, wearing glasses and lab coat, works alone and makes dangerous experiences in a lab (Kosminsky & Giordan, 2002; Reis et al., 2006).

So, it is important to bring our students closer to the real view of those who produce science and how science is produced, as pointed out:

> One must encourage children in school to reflect on science as a knowledge that helps explain the world and, at the same time, as a form of collective production, aligned with culture and human being ideas in his historical and social context." (Tomazi et al., 2009, our translation)

One way of breaking this mistaken view of science and scientific and technological production is by using cinema. This is a pedagogical resource that provides the student with scientific knowledge in a playful manner, capable of offering situations of exchange that enable the establishment of relations between scientific study and reality (Santos, 2019) and provide the student a wider view of certain concepts (Berk & Rocha, 2018). Moreover, the film provides keys and information that awake in the student's situations that stimulate curiosity and, according to the teacher mediation, encourage the desire to research (Santos, 2019).

It is known that many science teachers, while using cinema resources in classroom to explain science prefer to do so with science fiction genre (Berk & Rocha, 2018). That because these films usually make clear in their script the scientific theme. However, science fiction movies many times end up by corroborating the distance between science achievement and the doing of science, showing only the science product rather than its process. Otherwise:

> The didactic use of films contributes to more dynamic learning and directly related to the experience of the students. The aforementioned is not new and long been know. However, the barrier is not only encouraging its use, but the great challenge is on the modes of appropriation of this technology in the school." (Sousa et al, 2020, our translation)

Thus, it is interesting to use films where science is not shown as product and/or where the scientist is not depicted as a character, a stereotype. Cinema is an extremely effective cultural manifestation and can be used as a generator of debates, allowing reflections in the classroom (Silva et al., 2020). Furthermore, provides more dynamic activities, with the inclusion of sound and image appeal, allowing deep contact with the object of study (Bueno & Silva, 2018).

For such, certain animated films are ideal. They are more appealing, particularly for primary school children, and count on different instruments to create means to transmit feelings and emotions, integrating other forms of expression, and, based on the film plot and image, address aspects that can contribute to the learning process (Santos, 2019).

However, the insertion of film in classroom should be cautious, since these animated films were not produced concerned with precisely and faithfully informing about scientific knowledge (Vasconcelos & Leão, 2012). Our intention here is to present the main aspects in Kuhn's epistemology associated to the scientist's competences through films. But why are films good to present Kuhn's proposal?

According to Villani (2001), for Popper, the distinction between normal science and revolution is almost a caricature. Due to that, films are appropriate to explain Kuhn's epistemology. Since these important names of the philosophy of science disagree as to how the transition of scientific revolutions occurs [Kuhn argues that it occurs abruptly, with crises, while Popper argues that it is gradual (Popper, 1979)], in films it is easier to visualize Kuhn view of science, since the film short time makes it possible only to see the abrupt process of revolutions. Also, according to Bueno and Silva (2018), the films provide an involvement with the production, producing a type of unified reception of information, facilitating the abstraction of the message through these film productions.

However, we know that films will never completely show these aspects, and due to that we sought to analyze the converging aspects of the following films: "How to Train Your Dragon" (Arnold et al., 2010), "The Croods" (Belson et al., 2013), "Inside Out" (Rivera et al., 2015) and "Monsters, Inc." (Anderson, et al. 2001) and the work "The Structure of Scientific Revolutions" by Kuhn (2013), reminding that, according to Albert Einstein "imagination is more important than knowledge" (Einstein, 1929).

METHODOLOGY

Four animated films were analyzed in the light of Thomas S. Kuhn's epistemology (Kuhn, 2013): "How to Train Your Dragon" (Arnold et al., 2010), "The Croods" (Belson et al., 2013); "Inside Out" (Rivera et al., 2015) and "Monsters, Inc." (Anderson, et al. 2001). We searched in the films the presence of normal science and its respective paradigm, occurrence of research and extraordinary procedures and consequent scientific revolution and a new paradigm.

Through annotations on the need to present the scientific practice, the article "O ensino de ciências por investigação" (Teaching of science through investigation) (Lima, 2011), and the competences for scientific investigation indicated by authors Fumagalli (1993), Harlen (2000) and Howe (2002), as listed below, were also used:

- Observe with a purpose (seeking patterns or rare events);
- Describe what is observed;
- Compare and classify, with own or given criteria;
- Formulate investigative questions;
- Propose hypotheses and predictions;
- Plan experiments to answer a question;

- Analyze results;
- Seek to construe information in texts and other sources;
- Propose explanations to the results, prepare models;
- Argue based on evidences.

Using these competences as reference, we sought to survey the scenes where the characters demonstrated such behaviors during the animated cartoons revealing, similarly, the scientific process in the context of each animated film.

We can frame this research as qualitative, since, according to Oliveira (2012), it presents a flexible character, facilitating the description and concerned with construing the social realities, capturing meanings and understanding them.

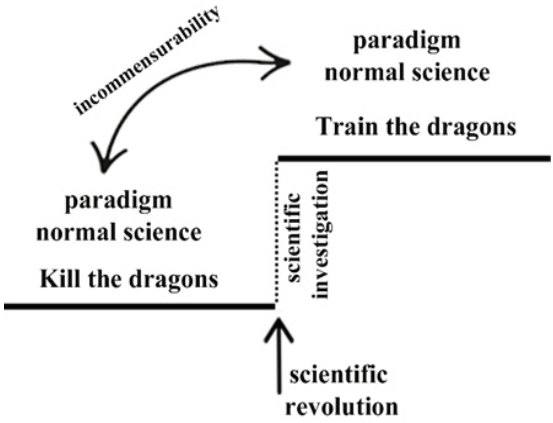
RESULTS AND ANALISES

"How to Train Your Dragon" (Arnold et al., 2010) and its relation with science process

Though being a fanciful context, with no relation whatsoever with a real and direct scientific content, it is interesting to observe in "How to Train Your Dragon" (Arnold et al., 2010) epistemological aspects addressed in a clear, systematic and very significant way.

In the beginning of the film, we see normal science facing the problem that afflicts the whole village of Viking de Berk (figure 1) where protagonist Hiccup lives. The constant attacks by dragons and the paradigm to which the whole community adheres: "we must kill the dragons". It is an established paradigm that leads the whole tribe to collectively think, with the same way of acting and talking, thus consolidating its culture, its normal science.

Figure 1
Process of scientific revolution in the film "How to Train Your Dragon" (Arnold et al., 2010). Based on Ostermann (1996)



One of the reasons why the normal science seems to progress so quickly is that its practitioners are concentrated in problems that only their lack of skill can prevent from solving (Ostermann, 1996).

The protagonist, however, does not fit in this paradigm, which generates a series of questioning (**investigative questions**).

Therefore, he starts to dedicate to an extraordinary research and a series of extraordinary procedures revealing the competences associated to the procedures for a science investigation (table 1):

Table 1
Competences present in film "How to Train Your Dragon" (Arnold et al., 2010) associated to the character Hiccup.

Competences	Film scene
Observe with a purpose (seeking patterns or rare events)	Observations of Toothless in the valley [00:28:00 - 00:33:12].
Describe what is observed	He draws the dragon in the notebook [00:21:15].
Compare and classify, with own or given criteria	When he tries to list Night Fury characteristics in the book of dragons [00:24:42].
Formulate investigative questions	"Why doesn't it fly?" [00:21:21]; "Why didn't he kill me?" [00:20:05].
Propose hypotheses and predictions	When he confirmed in the training dragons what he observed in Toothless [00:35:26 and 00:38:50 or 00:39:40 – 00:39:53].
Plan experiments to answer a question	When he sought to develop tools to fly along with Toothless [00:34:40 – 00:36:28 and 00:39:08 – 00:39:32].
Analyze results	Every time he could not make Toothless fly, he analyzed to see what went wrong [00:39:27].
Seek to construe information in texts and other sources	He looked for information in the book of dragons [00:23:14 – 00:24:42].
Propose explanations to the results, prepare models	He explained that dragons would only attack when they felt threatened and for being forced by the Dragon Chief [01:05:30].
Argue based on evidences	He tried to convince the tribe by showing that it is possible to tame the dragon [01:02:42].

In the beginning of the film, we can already notice the protagonist attempt to use technology rather than strength, normally used by Vikings, to subdue a dragon.

He is eventually successful, reaching a practically unknown dragon (the Night Fury). When Hiccup captures and hurts the dragon, named Toothless, the dragon was stuck in a situation that enabled Hiccup to study it, thus starting a "research project", a good example in the film. We can observe a series of scientific competences executed by Hiccup, like the **investigative questions**: "Why can't he fly?" and "Why didn't he kill me?".

In several moments the character demonstrates to make **observations with a purpose, seeking patterns and rare events,** for example, when he noticed the dragons' fear of eels, the contact with the grass, the way they react when they are touched in the neck and the light.

He **describes what he observes** in several situations, like when he draws the dragon tail project and when he attached the Night Fury drawing in the notebook of dragons. In addition, he seeks to **construe information from texts** like the book of dragons.

He **proposed hypotheses and predictions,** like when he applied to the training dragons the observations of Toothless he made. He **planned experiments to answer a question:** "Why can't he fly?" which guided the preparation of a series of prostheses, saddles and outfits and instruction manuals to try to answer this question.

Hiccup **analyzed the results,** for example, at each attempt to touch Toothless in the beginning of the film and in face of the results obtained in the tests with the other dragons. Eventually, he reflects that everything they know about dragons is wrong, revealing the incommensurability of the old paradigm with the new one.

He **proposed explanations to the results and prepared models** that fitted in the data obtained, since he could fly with Toothless and developed training techniques that prevented the dragons from killing him and he also discovered that an alpha dragon made the other dragons attack.

Finally, he sought to **argue based on evidences** about the need of a new paradigm in the final test of his training, before the whole tribe, renouncing to his own Viking identity with regard to the dragons' paradigm.

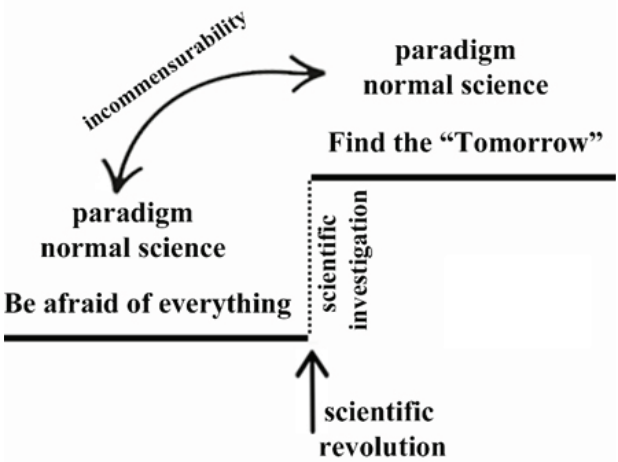
This whole research developed by the character shows the development of technologies and new knowledge and its applications. So, he can first convince Astrid, then his friends. According to Kuhn, youth who usually are not very much involved in the old paradigm are those who bring the shift (Kuhn, 2013), and so the character can convince the whole trivet to accept the new paradigm, thus generating a scientific revolution. Therefore, this film presents high potential to teach students the competences associated to science investigation procedures.

"The Croods" (Belson et al., 2013) and its relation with the science product

In "The Croods" (Belson et al., 2013) there are direct scientific contents that can be analyzed, for example, the meeting of Neanderthals and *Homo sapiens,* since in the archaeological aspect there are strong evidences that corroborate this happening, despite the fancy scenario associated to environments, flora and fauna in the animated film.

Again we notice a problem (or several) involving the protagonist Eep, which is to guarantee the survival of all in situations as adverse as hunger and dangers. The family deals with these problems like the well-defined normal science constantly reinforced by the father figure (Grug), by imposing strict rules and due to the orality practice with narratives that justify the paradigm. They solve their problems using physical strength, collective work and discipline based on the father authority and the current paradigm is: "Fear everything! The new is bad!" (figure 2).

Figure 2
Process of scientific revolution in the film "The Croods" (Belson et al., 2013). Based on Ostermann (1996)



The Croods represent the family that could better adapt to the hostile environment, chiefly due to their way of thinking, acting and talking, as established by Grug when they had to seek shelter in their cave at any sign of danger.

However, the main character (Eep) is constantly questioning (**investigative questions**) the paradigm imposed to the family: "Why do we do this?" or else "Why do we have to live in the cave?" We can notice her making **observations in search of rare events** when she goes after a light at night from a fire (made by Guy, the new character), breaking the rule about going out of the cave at night (table 2).

Table 2
Competences present in film "The Croods" (Belson et al., 2013) associated to the family

Competences	Film scene
Observe with a purpose (seeking patterns or rare events)	Eep observes the light of the fire at night [00:14:38 - 00:19:45]; The mother and the grandmother observe the "frog" passing by among carnivorous plants [00:57:25 – 00:58:40].
Describe what is observed	The father drawing on caves' walls [01:20:30 – 01:21:20].
Compare and classify, with own or given criteria	When he classifies animals in edible and not edible (pets) [00:39:35].
Formulate investigative questions	"Why do we do this?"[00:11:45], "Why do we live in caves?" [00:11:46], "From where do these ideas come?" [00:51:45].
Propose hypotheses and predictions	Guy makes predictions about the end of the world [00:20:39 – 00:21:00 or 00:36:25].
Plan experiments to answer a question	When the father throws Guy to find out whether there is a safe place in the other side (Reminding that Guy volunteered) [01:15:08 – 01:16:35].

Competences	Film scene
Analyze results	They analyze the abundance of food and discover the concept of "leftovers". [00:44:31 – 00:44:50].
Seek to construe information in texts and other sources	Guy construes information by listening to the sounds in the soil through a shell to predict the "end of the world". [00:20:15].
Propose explanations to the results, prepare models	When he explains that ideas come from the brain [00:51:51].
Argue based on evidences	Guy argues using utensils to show what is best for the family [00:42:25 or 00:50:55 or 00:52:47 or 00:55:39].

It is interesting to notice that in the film an external factor occurred that placed the family in a wider environment, since the cave (which represented a static world, without changes) was destroyed, leading them to a new world full of uncertainties, so that their old paradigm could no longer produce results for the new problems.

Guy is himself the personification of the new paradigm. He acts alone, resorts to his ideas rather than to strength to solve problems, develops utensils and useful tools, believes in each person individuality and in focused on tomorrow (the future) rather than fear (the past). All these characteristics keep his mind open to see new possibilities and learn with each situation.

The process he uses to develop the "products" (torch, shell, shoes, umbrella, trap, wooden legs, etc...) presented to the family that helped them solve some problems is not clear. However, it is clear that Guy **argues based on evidences,** showing how the products were important for the family daily routine in this new scenario. Besides, Guy plays an important role while noticing that the "end of the world" is coming, because he is doing relevant **predictions** to save the family.

Guy, with his new paradigm, **classifies animals with own criteria,** revealing the possibility of them having pets (which are not eaten), **plans traps (experiments) to answer to questions** like how to get food. The family, while **analyzing the results** of this experiment, finds out what the Word "leftovers" mean.

Guy then **proposes an explanation for the results** of his ideas saying that they come from the brain, and also prepare models showing the importance of creativity and thought for the development of new technologies, in a deductive way, without much emphasis to the process.

As Guy is released from the trunk, he systematically solves a series of problems that Grug, with his way of thinking and acting, cannot solve, revealing the extraordinary science of the new paradigm and the gaps in the old paradigm.

Throughout the story, the family is gradually convinced to accept the new paradigm, beginning with Eep (again the younger ones) and then the rest of the family, which can leave the labyrinth when they put into practice the competences taught by Guy. The mother and the grandmother had to find out how to pass through carnivorous plants, and for that they **observe** a frog passing by them. Then they proposed a **hypothesis** using

a flower and their brain and **analyzed the result** when they finally reached the other side. Eep' brother, while meeting an animal, also observed that as he throws a stone the animal would bring it back to him, and analyzed the result of his interaction with the animal and tamed it.

Finally, Guy **proposes an explanation** for the concept of the "tomorrow" that he seeks, while taking the family to the tree tops at night, and while putting out the torch fire, and looking at the starry sky **prepares a model** saying that the sun goes to that place when it sets, also characterizing an argument based on evidences that convinces almost the whole family to follow Guy, only the mother demonstrates that they should remain with Grug.

It becomes clear when the family finally finds a new cave and Grug tries to push them into it, but they all refuse to enter, revealing the incommensurability of the new paradigm accepted and the older one now rejected. The mind that opens up to a new idea never returns to its original size" (Albert Einstein)

Grug, in his turn, personifies the debate between two paradigms, showing how hard and clear is the transition. We can see that it took three steps for him to be persuaded:

1st) He decides to have new ideas that are not associated to problem solving, simply because he believed his mother-in-law would die if she had a new idea.

2nd) He recognizes that he needs Guy's ideas when they are stuck in the pitch.

3rd) He can finally have his own ideas to solve the problem and cross the abyss that separates him from his family by making an experiment based on observations of rare events.

Finally, the whole family is convinced and adapt better to the new environment.

"Inside Out" (Rivera et al., 2015): relationship between thesis and antithesis

The animated film "Inside Out" (Rivera et al., 2015) occurs in a fantastic scenario that represents how the mind of preteen Riley Andersen works since her birth.

Her mind is like a dashboard where we find five typical emotions with apparently well-defined functions that alternate the panel control:

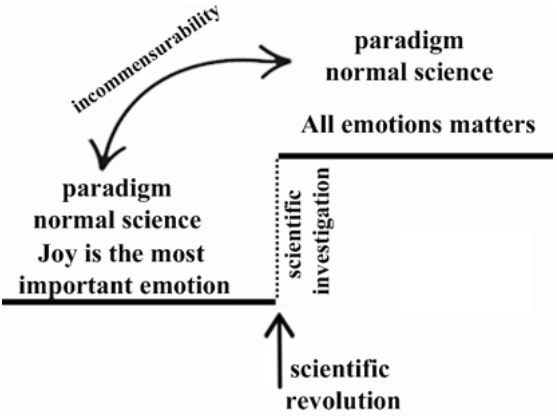
- Fear: protects Riley from getting hurt;
- Anger: protects Riley from alleged injustices;
- Disgust: protects Riley from physical and social poisoning;
- Joy: its apparent function is to make Riley happy;
- Sadness: at first it is not clear what its function is.

So, the problem the emotions are trying to solve is how to make Riley happy and healthy.

The story shows that everything is well with Riley and the emotions show a very efficient modus operandi to make her happy (normal science), demonstrating relative success, as revealed by large part of joyful memories represented by yellow spheres. The five memories that form the basis of Riley personality are also yellow.

We observed that the normal science in the beginning of the film is characterized by the dominating leadership of Joy emotion (fig. 3) over all the other emotions, and total disregard to Sadness emotion (paradigm), seeking to avoid at the most its access to the controls.

Figure 3
Scientific revolution process in film "Inside Out" (Rivera et al., 2015). Based on Ostermann (1996)



In several situations we observe Joy questioning (**investigative question**): "What is Sadness for?" (table 3).

Table 3
Competences present in film "Inside Out" (Rivera et al., 2015) associated to character Joy.

Competences	Film scene
Observe with a purpose (seeking patterns or rare events)	Joy observes how Sadness can comfort the Bing Bong [00:49:26]; Joy observes the happy memory that was a sad memory in the past [01:09:19].
Describe what is observed	When the emotions observe the new house and each one starts to create new memories [00:09:27].
Compare and classify, with own or given criteria	Scene where memories arise that are a mix of emotions [01:23:18].
Formulate investigative questions	Joy asks: "What is Sadness for?" [00:04:30].

Competences	Film scene
Propose hypotheses and predictions	Scene where Joy proposes the idea of making a dream so happy that will wake Riley up [00:53:11].
Plan experiments to answer a question	Scene where Joy asks Sadness to try to take out the idea from Riley's head [01:19:23]. And when she hands over the base memories to Sadness [01:20:27].
Analyze results	When the emotions analyze the new personality islands [01:24:02].
Seek to construe information in texts and other sources	When Sadness studies the brain manuals [00:15:15].
Propose explanations to the results, prepare models	When Sadness explains the abstraction process step by step [00:42:05].
Argue based on evidences	When Riley argues with her parents explaining why she is sad, in the end of the film [01:21:43].

Everything goes well until something unexpected occurs: the family moves to a new city. That generates a series of problems that the current way to conducting the mind cannot cope with, that is, a paradigm crisis.

With the **observations' descriptions** made by the emotions, of the new city and the new house, and distant from the references that strengthen their base memories, Joy starts to lose control, generating countless memories of several emotions, reaching a critical situation where a sad base memory can be produced, thus evidencing a recognized anomaly that it is not really assimilated by the existing paradigm.

While trying to prevent the blue base memory (sad) to create a new personality island, Joy and Sadness are thrown out of the dashboard, forcing the two emotions to a very close relationship while the try to go back to the panel.

In this journey, Joy enters into several new situations and get to know Sadness and the brain functioning deeper. Sadness, for having studied the manuals, **construes the information** in these texts and can show the way back to Joy.

Joy also **observes** that Sadness can motivate the Bing Bong, something she herself could not do. An extraordinary episode marking the crisis of the prevailing paradigm (represented by Joy).

In a scene where Joy, Sadness and Bing Bong try to wake Riley, Joy **proposes the hypothesis** that a very joyful dream can wake her up, however, it is Sadness hypothesis that makes a right prediction, creating a scary dream to wake her up, representing a sort of **planning of an experiment to answer a question.**

Several situations occur where Joy decides against Sadness suggestion and that she will later notice that it was wrong. Finally, in a critical moment, apparently hopeless, where Joy falls into the memory dump, she can notice Sadness role, because she could feel what Sadness feels, and, **while analyzing the result,** send a happy memory back and see that it was initially sad. Thus, Joy implicitly proposes an **explanation to the Result and generates a new model.**

Joy then can leave the memory dump thanks to Bing Bong sacrifice, finds and recover Sadness and together they go back to the dashboard to solve a serious problem that other emotions could not solve. In this context Joy, **to argue based on evidences** and convince the other emotions of his new model, she, against the other emotions' expectations, asks Sadness to assume the dashboard, to remove a self-destructive idea motivated by the resentment in Riley's head and it works out. Therefore, Riley decides to get off the bus and go back to her parents' house.

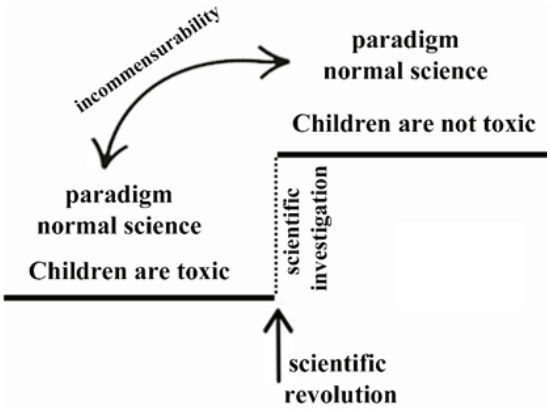
Finally, Joy makes something unthinkable, she hands over to Sadness the five Joyful base memories, transforming each of them into a sad memory, so that Riley could say goodbye to a happy past that would not come back. That enables the construction of new memories and the reconstruction of a mature personality, more prepared to the new stage they were living. So, a new paradigm arises where all emotions are important, the characters **compare and classify with own criteria** the new memories and at the end they **analyze the result** of this new paradigm while observing the new personality islands and the new dashboard, physically representing the incommensurability with the old paradigm.

"Monsters, Inc." (Anderson, et al. 2001) and Scientific Investigation by chance

The animated film "Monsters, Inc." (Anderson, et al. 2001) reveals a very unusual corporate scenario with an easily noticeable normal science where there is a whole culture created based on two simple ideas:

- Children are toxic - paradigm (fig. 4);
- Scream is the source of energy.

Figure 4
Process of scientific revolution in film "Monsters, Inc." (Anderson, et al. 2001). Based on Ostermann (1996)



Thus, there is a way of thinking, talking and acting turned to solve the problem of energy demand of the city that apparently depends on the skills of monsters that are professionals in scaring children without touching them.

The monsters that do this job must have a very scary profile and their behavior must be likewise horrific. The story's main character, James Sullivan, is the most adapted inside this normal science, and was always chosen the employee of the month.

However, things start to change when, while checking one door to access the room of a child, outside working hours, he accidentally lets a child, Boo, enter the world of monsters and since he could not put her back into the door, he must bring her home.

Fear and despair take over the characters (Sullivan and his friend Mike Wazowski), but an affective relationship between Boo and Sullivan is gradually established. Sullivan starts to notice that the child is not toxic (recognized anomaly) and he also **observes** strange phenomena that occur in certain situations when Boo laughs, making him **formulate an investigative question** about this phenomenon (table 4).

Table 4

Competences present in film "Monsters, Inc." (Anderson, et al. 2001) associated to characters Mike and Sullivan. The competence "Seek to construe information from texts and other sources" was not found in the film.

Competences	Film scene
Observe with a purpose (seeking patterns or rare events)	Scene where Sullivan notices the energy behavior when Boo laughs in his apartment [00:30:47].
Describe what is observed	Scene where Mike describes to Waternoose that children are not toxic [00:56:11].
Compare and classify, with own or given criteria	In the end of the movie when the monsters are compared and classified according to their capacity to make laugh [01:23:51].
Formulate investigative questions	When Sullivan asks: "What was that?" after Boo laughs [00:30:53].
Propose hypotheses and predictions	When Sullivan starts to propose to Mike that Boo maybe was not so dangerous (toxic) [00:34:22].
Plan experiments to answer a question	When Mike dresses up Boo to enter the company without being noticed [00:34:50]
Analyze results	When Sullivan asks Mike to make Boo laugh so that he could light up the doors [01:09:00]
Seek to construe information in texts and other sources	----------
Propose explanations to the results, prepare models	When Sullivan tells Mike that his performance was good because laughter is 10 times more powerful than scream [01:22:48].
Argue based on evidences	When Mike argues based on Waternoose talk recording, the criminal scheme in the company [01:16:10].

While attempting to return Boo to her house, Sullivan presents **hypotheses and predictions** that Boo was not toxic, and **plans an experiment** that is to dress up Boo as if she were a monster, so that would not be detected by the child detection teams. Mike

describes the observations about Boo not being toxic to Waternoose, the company's CEO, and accidentally they find out a secret scheme for kidnapping children, headed by Waternoose himself and his employee Randall, intended to solve at any cost the energy crisis the monsters were living in.

Mike and Sullivan reveal their crimes **arguing based on evidences,** through a video recording, which takes to prison Waternoose and Randall. However, this situation can generate the bankruptcy of the energy company Monsters, Inc.

But there is a turnaround and Sullivan can synthesize the information obtained while staying with Boo, **prepares a new business model** and presents a new paradigm (fig. 4) that will save the company and solve the energy crisis.

While analyzing the results, that the laughter of children is a source of energy 10 times more powerful than screams (scientific revolution), thus totally transforming the way the company works and making clear that children are not toxic (a new paradigm, showing the incommensurability). In addition, there is a new comparison **and classification of employees, with own criteria,** associated to the capacity of making laugh. We understand that this change in energy source (from scream to laughter) reflects the paradigm shift but it is not a paradigm shift itself.

The affection of Sullivan for Boo made him worry more with her than with the successful life style he achieved over the years of work in partnership with his best friend Mike, almost sacrificing this friendship, which enabled the Discovery of a paradigm that was better than the previous one.

Thomas Kuhn in films

Certain patterns were observed in these animated films that can be associated to Kuhn's epistemology (table 5). In all films we noticed the presence of a normal science guiding a series of activities in the light of a paradigm, the existence of circumstances that make the characters stay away from the influence of the prevailing paradigm to be able to notice the anomalies. We also noticed the presence of the extraordinary science and the emergence of a "scientific" revolution and its new paradigm as a result of several procedures of scientific competence.

Table 5
Summary of Kuhn's epistemology in all films analyzed.

	How to train your dragon	The Croods	Inside Out	Monsters, Inc.
Paradigm	We must kill the dragons	Fear everything! The new is bad!"	Keep Riley as happy as possible without being sad.	Children are toxic
Normal science	Ways of thinking, speaking, dressing and acting with purpose to kill dragons - Specializations for killing dragons.	Specializations in survival based on strength, collective work and hiding in the cave.	Specializations in making Riley happy, with all emotions being under the control of Joy, always trying to nullify Sadness.	Specializations in scaring children without touch them.
Recognized anomalies	A dragon did not attack to kill; a dragon not able to fly.	The fire that shines at night and protects from animal attacks; practically the new world outside the cave.	The change from a happy to a sad memory when touched by Sadness, leading the emergence of a sad base memory; Sadness succeeded to motivate Bing Bong.	They were in contact with a child and did not get intoxicated; the great amount of energy generated by the laugh of a child.
Scientific revolution	Train the dragons	Find the "Tomorrow"	All emotions matters	Children are not toxic.
Extraordinary science	Tame dragons and ride them.	Create several useful tools and strategies for daily problems.	Base memories with mixed emotions; The rise of new islands of personalities; installation of a more "complete" dashboard.	Make children laugh and extract ten times more energy than scream.

Both in "Inside Out" (Rivera et al., 2015) and in "Monsters, Inc." (Anderson et al., 2001), the persuasion of the paradigm shift came from those that were most adapted to the normal science, and the transition was kind of calm, similar, in this aspect, to the view proposed by Popper maybe, while in "How to Train Your Dragon" (Arnold et al., 2010) and "The Croods" (Belson et al., 2013) there is a violent clash in the transition from normal science to the new paradigm, represented by the resistance of those more adapted to the normal science (Stoick – Hiccup's father, and Grug - Eep's father) to the discoverers of the new paradigm (Hiccup and Guy).

These films reveal in a simple and accessible way good symbolic representations of how scientific revolutions can occur as consequence of the competences of scientific investigation procedures in different ways and distinct scenarios, enabling the significant understanding by primary school children of elementary concepts of the Philosophy of Science, which will initiate their scientific literacy. Another aspect we can observe in these films, based on Kuhn (2013), is that:

"There are, in principle, only three types of phenomena about which a new theory might be developed. The first consists of phenomena already well explained by existing paradigms. A second class of phenomena consists of those whose nature is indicated by

existing paradigms, but whose details can be understood only through further theory articulation. Only when these attempts at articulation fail do scientists encounter the third type of phenomena, the **recognized anomalies** whose characteristic feature is their stubborn refusal to be assimilated to existing paradigms".

In the four films, the characters broke the paradigms, made observations in natural environments about the objects of study at issue, without the "commitment" with the old paradigm thought, in other words, outside the control situation, enabling more contact with the **recognized anomalies,** main source of new theories, and softening the previous paradigm, providing room to a new and incommensurable paradigm.

For example, in "How to Train Your Dragon" (Arnold et al., 2010) Hiccup observes the Night Fury, personification of a recognized anomaly, in a natural context, enabling a softening of the old paradigm, differently from the other dragons in their cages used for training Viking (physically and metaphorically, within the current paradigm).

CONCLUSIONS

The present work intended to show that the films make an artistic representation of situations where Kuhn concepts can be taught in a clear and significant way.

However, it is our duty to indicate a limitation to this use, because the collective work of researchers is not shown in any of the films, so the teacher must point that out not to corroborate the image of a lonely scientist that solves everything by himself (Tomazi et al., 2009).

We can also expect that it the students can identify behaviors of scientists in films that are not intended to be a faithful representation of reality, these students can also notice such occurrences in other different contexts.

Other films also have this potential to represent Kuhn's concepts and reveal the procedures of science investigation in classroom, like for example: The Boy Who Harnessed the Wind (Calderwood et al., 2019); A Bug's Life (Anderson et al., 1998); Take the Lead (Godsick et al., 2006); Avatar (Cameron, 2009); Freedom Writers (DeVito et al., 2007); Moneyball (De Luca et al., 2011).

It is also important to understand the children from primary schools, that are beginning their knowledge of science, are not yet inserted in a normal science, so that when they learn about scientists' competences, and adhere to them, they will be open to rethink the normal science and seek the development of new paradigms.

AUTHORS' CONTRIBUTIONS STATEMENTS

MVMO conceived the presented idea; MVMO and AF developed the theory, MVMO and CH development the methodology; all authors actively participated in the discussion of the results, reviewed and approved the final version of the work.

DATA AVAILABILITY STATEMENT

The data availability statement is not applicable, as no new data was created or analysed in this study.

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