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A Critical Analysis of the Democratic Argument for Teaching Science: The Case of Cell Phones

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Abstract: A number of diverse arguments have been proposed by researchers of science education regarding the reason science should be taught in schools. These arguments inevitably play a crucial role in the curriculum designed by policymakers. The present study turns its attention to the democratic argument. It explores its validity through a special socio-scientific issue that citizens are likely to encounter in their everyday life, that of radiation emitted from cell phones. In particular, it tries to study the required knowledge of physics that will enable individuals to effectively deal with the emission of radiation from cell phones. Moreover, drawing from sharp conflicts that have arisen during the last years around the world between citizens and cell phone companies regarding the installation of cell towers within residential areas, it tries to record information about different places in the world where the cell phone controversy has made headline news.

Keywords: democratic argument; science education; cell phones

Introduction

Quite a few authors, during the last decades, have expressed their opinion about the public understanding of science. While the great majority agree that we should teach science to all, within compulsory schooling, there is a debate about why and how we should do it. Thomas and Durant (1987) point out 5 arguments for teaching science: the economic, the utility, the democratic, the social, and the cultural argument. The economic argument suggests that teaching science will ensure the need for a continual supply of science graduates to the science profession, contributing to a nation's financial wealth. On the other hand, the utility argument proposes that teaching science is likely to help people deal with a number of technological devices that are apparent in modern, 21st-century societies. The democratic argument points out that scientific knowledge enables individuals to engage in debates and fulfill their role as active citizens while the social argument states that a scientifically literate person is likely to feel more in sympathy with the aims of science. Finally, the cultural argument suggests that science is a major achievement of human culture and so it should be taught to people just like history, music, and art. In what follows, the democratic argument will be thoroughly examined (Hewitt, 2014).

Theoretical Framework

In an ever-changing society that is overwhelmed by technological innovations but also faces great socio-scientific issues, more and more focus is put on the public understanding of science. The latter stems from education aiming to equip students with the appropriate tools such as knowledge and skills as well as ethics, values, and key principles towards scientific literacy and democratic citizenship (Erduran & Kaya, 2016; Ottander & Simon, 2021; Sengul,

2019). This focus is apparent in the research literature judging from the increase in the papers related to argumentation for science teaching and learning (Erduran & Kaya, 2016) but also in the science education curricula (NGSS Leads States, 2013; NRC, 2012; Institute of Educational Policy, 2021). Scientific knowledge as well as the skill set is necessary because it enables citizens of any age to comment on other's ideas, express their own opinions, influence decision-making, and contribute to societal discussions about various socio-scientific issues (Erduran & Kaya, 2016; Osborne & Dillon, 2008; Ottander & Simon, 2021). In addition, the ethical aspect stands for values and principles that are important to be apparent in a democratic context such as the solidarity among persons for the greater social good. In general, the socio-scientific issues incorporate scientific as well as social (Driver, 1996), ethical (Ottander & Simon, 2021), and even political dimensions (Erduran & Kaya, 2016), and they are considered a vehicle to develop scientific literacy (Ottander & Simon, 2021; Roberts & Bybee, 2014). So, for example, the question of whether we should clone a living organism or not is a socio-scientific issue, as it contains an ethical dimension. Indeed, many people have expressed their opposition to cloning as they believe that it contradicts human nature. For them, we are not 'ethically' allowed to produce human beings in a laboratory. On the other hand, there are quite a few who support cloning, as they believe that it can serve medical purposes. According to the democratic argument, basic knowledge of biology is required to express a substantiated opinion on such an issue from the scientific perspective. Nevertheless, a socio-scientific issue as such includes values, norms, and ethical aspects which are interlaced with science (Ottander & Simon, 2021).

Furthermore, a socio-scientific issue may have a political dimension. As Prewitt (1983) accurately points out, people encounter in their everyday lives a political agenda that is rapidly getting more difficult to be understood by the laymen. Therefore, people should have basic scientific knowledge in order to be able to cope with this agenda. Recently, for example, there is a great political debate going on about the use of chemical weapons by riot police to disperse protesters. According to the democratic argument, scientifically literate citizens are likely to have an effective contribution to such a discussion. Scientifically literate citizens, the argument goes, have an understanding of the chemical substances that are used as well as the bad effects they can cause on both the environment and our health. Therefore, their contribution would be essential in the latter discussion. Moreover, they would be able to present documentary evidence to substantiate their arguments. As a result, their manifestation of disagreement is likely to be taken seriously by anyone who supports the police's stand. Towards this direction, science can lead to a consensus course of action in a normative way (Östman & Almqvist, 2011; Rudsberg & Öhman, 2015) and even sometimes weaken conflicts that stem from the socio-political aspect of the socio-scientific issue (Levinson, 2010; Simonneaux, 2014).

Finally, a socio-scientific issue may be connected to the long-term effects that human activity is likely to have. It is a fact that people have the tendency to underestimate the consequences of their actions which are likely to occur in the distant future (Jenkins, 1999). Especially, when they are not aware of the scientific dimension of the problem, they often do not take seriously any warning against activities that may have catastrophic consequences in the future. The 'greenhouse effect' is such an example. In particular, someone who has been taught in school about this phenomenon

is likely to consider in a more conscious way that the hazard of the melting of the icebergs is not a science fiction scenario but a tangible reality. Consequently, such a person is likely to react and take active action against all these activities which may have catastrophic consequences for our planet in the future, and/or to raise awareness among his peers.

On the other hand, there are many authors who have expressed more skeptical views about the democratic argument. Millar (1996) claims that the level of scientific comprehension that students gain in school is inadequate to help them in real decision-making. Indeed, in real life, a potential problem has so many dimensions that one cannot deal with by using basic scientific knowledge. Therefore, for example, if someone has been taught elementary-level nuclear Physics, it is unlikely to have adequate knowledge to participate in a debate about whether an explosion in a specific nuclear power plant is possible to occur or not (Millar, 1996). Interestingly, quite often there seems to be inconsistency between the acquired knowledge of an individual and the way he finally acts and behaves (Howe & Krosnick, 2017). This is well reflected in a smoking issue where people tend to continue this habit despite their deep understanding of the serious consequences of it (Lee et al., 2017).

In addition, Jenkins (1999) points out that in practice '*in deciding how and when to act in practical matters that have a scientific dimension, scientific knowledge is considered alongside this other, experiential and personal knowledge base*' (Jenkins, 1999, p.705). So, for example after the Chernobyl disaster, farmers considered a number of factors that scientific advice failed to accommodate (Jenkins, 1999). In particular, farmers did not deal with all farms in the same way, i.e., as a homogenous group, but they considered the differences between them. This is due to the fact that two farms are likely to have great differences, even if they stand in the same valley. Moreover, the farmers narrowed down their research to the grazing lands where most flocks of sheep used to graze (Jenkins, 1999). What is more, they took into account a number of other factors in order to ensure that the results of the field experiments would be reliable.

Judging from the above, even if Jenkins' point is valid, the democratic argument cannot be abandoned. Undoubtedly, school scientific knowledge cannot ensure that everyone will have an adequate solution for every problem. Nevertheless, a fundamental understanding of science gives the opportunity to the individual to express his own point of view on a number of socio-scientific issues (Millar, 1996). The Royal Society (1985) put it very well by stating that while a wider understanding of the scientific aspects of a given issue will not automatically lead to a consensus about the best answer, it will at least lead to more informed, and therefore better, decision-making. Therefore, science education could move in this direction and try to play a key role in the development of critical thinking which forms the basis of active and effective citizens (Abrami, 2008; Behar-Horenstein & Niu, 2011; Marin & Halpern, 2011). The latter also validates Robert's views (2007), who discerns that scientific literacy which is related to the obtained scientific knowledge from literacy which is related to real-life situations (Ottander & Simon, 2021). In the latter case, a certain perspective of democratic participation is proposed where researchers argue for a science education that includes social change and socio-political actions in relation to learning (Bencze & Carter, 2011; Hodson, 2003 as cited in Ottander & Simon, 2021) adopting an activist approach.

Democratic Education in Greece

In Greece, citizenship education is offered as a compulsory separate subject in Greek curricula (EACEA, 2017). Nevertheless, the title and content of the course are largely depended on socio-political and ideological context. In terms of educational policy, deliberative democratic education is pursued according to Sant's (2019) review and classification into eight types. According to the latter research, deliberative democratic education concentrates on acquiring skills and values for public deliberation (Fraser-Burgess, 2012; Haav, 2008; Lefrançois & Ethier, 2010 as cited in Sant, 2019). This is sought through problem-solving situations (Haav, 2008 as cited in Sant, 2019) connected to students' everyday activities and interests, in which they investigate real-life problems (Gibson & Grant, 2012; Lefrançois & Ethier, 2010 as cited in Sant, 2019) coming to the most functional solution. The former entails interdisciplinary approaches with which students can explore an issue from multiple perspectives until they reach a consensus (Camicia, 2009; DiCamillo & Pace, 2010; Lan, 2013; Lo, 2017; Stitzlein, 2011 as cited in Sant, 2019). Furthermore, controversies are used by educators (Fallace, 2016; Payne, 2017; Tannebaum et al., 2015 as cited in Sant, 2019) to engage students and help them overcome the contradictions that may occur. Of course, as an interdisciplinary approach, not only other learning areas such as language (Payne, 2017 as cited in Sant, 2019) mathematics, history, and philosophy (DeCesare, 2012 as cited in Sant, 2019), etc. are involved, but also arts (art, dance, drama) (Catalano & Leonard, 2016 as cited in Sant, 2019) as a mean for expression. The aforementioned attributes are consistent with science education in Greece, which fulfills to secure democracy through the inculcation of critical thinking in children and young people.

As a matter of fact, in Greece, an educational initiative was recently put into practice to strengthen STEAM with the recent entry of the skills workshops in the compulsory, weekly schedule of all levels starting from pre and primary education. The purpose of the 'Skills Workshops' is to strengthen students' soft skills, life skills, technology, and science skills in order to enable them to act as depositaries of public interest values for the greater good, democracy is one of them. Furthermore, students are sought to be equipped with the appropriate tools to better use their knowledge and respond to the challenges of an ever-changing environment. To this extent, the Greek Institute of Educational Policy (IEP) has invited all educational institutions and providers to submit relevant educational materials in order to enrich the initiative's resources (IEP, 2022). The present study, following the abovementioned frame, examines the democratic argument for teaching science.

Research Questions

The present study aspires to explore the democratic argument of teaching science through a distinct socio-scientific issue that citizen is likely to come across in their everyday life, that of radiation emitted from cell phones. In particular, it seeks to answer the following two research questions:

1. What is the required knowledge of physics that will enable individuals to examine the emission of radiation from cell phones in an effective way?
2. Which places in the world have made the cell phone controversy headline news?

Results

Research Question 1: What is the required knowledge of physics that will enable individuals to examine the emission of radiation from cell phones in an effective way?

An exemplary paradigm of the socio-scientific issue lies in whether the use of cell phones can have a bad impact on our health. Undoubtedly, in the last two decades, people tend to use cell phones, along with other devices such as smartphones and modern game consoles, to a very high degree (Nasser et al., 2018; Piper et al., 2019). While it is a fact that current research findings do not suggest a close correlation between cancer and cell phone usage, health hazard effects cannot be excluded in the long term as cancer may need more than twenty years to form and grow (Gavrilas et al., 2022). Consequently, individuals seem to hold rather negative feelings about the potential risks of mobile phone radiation. This, to a large extent, is related to the way the media deal with the notion of 'radiation'. That is, the term 'radiation' is often associated exclusively with 'radioactivity' that characterizes nuclear energy, X-rays, gamma rays as well as alpha and beta particle radiation (Burcin & Ince, 2010). All these terms lie at the heart of debates regarding nuclear power plants that take place on the radio, TV, and various websites (Neumann & Hopf, 2012). In addition, the use of language in everyday contexts contributes to the misunderstanding of the term radiation (Neumann, 2014). Indicative is the German language, where the term 'Strahlung' stands both for the radiation and the notion of the Sun. As a result, the phrase 'the sun is shining' is often considered equivalent to the phrase 'the sun is radiating' (Neumann & Hopf, 2012).

In addition, according to the democratic argument, people should hold a basic understanding of the electromagnetism spectrum, which is a basic element in the whole theory of electromagnetism. Particularly, they should know that the electromagnetic spectrum is divided into the ultraviolet (UV), visible light, and infrared radiation (IR) and is extended even further from gamma rays to radio waves (Hewitt, 2014). What is crucial to be understood here is that the only thing that differentiates all these kinds of radiation is their frequency. Indeed, each frequency can produce a wave with a specific wavelength. It is the length of this wave that determines its place on the electromagnetic spectrum. So, for example, the difference between an infrared wave and an X-ray is just that the former has a smaller wavelength than the latter (Young et al., 2004). Moreover, people should get a basic knowledge of the mechanisms involved in energy absorption. As soon as radiation approaches the body, the molecules of the body absorb it, and depending on the radiation frequency they start vibrating. It is this kind of vibration that inevitably leads to the heating of the body. A physical quantity called the 'specific absorption rate' (SAR) defines the levels of absorption (Gavrilas et al., 2022).

Apart from the electromagnetic spectrum, people should have a basic understanding of the technology which is related to cell towers in order to have more chances to promote an effective debate with the cell phone company (Levitt & Lai, 2010). Specifically, they should know the relation which exists between a source and a detector. It is important to know that the antenna (source) emits electromagnetic waves at a specific frequency and with a specific wavelength. These waves travel unimpaired through the air until they hit another object (detector). When this happens, the waves can be reflected, absorbed, or transmitted by the object. The absorption of an electromagnetic wave depends both on

the frequency of the wave and the material of the object. If the detector is the human body, then specific electromagnetic frequencies can be harmful (Young et al., 2004). Moreover, people should be aware of the way that cell tower emits radiation. It is a fact that even if radio waves travel through all directions, there are different zones of their concentration. The lowest proportion of radio waves is directly under the tower, whereas the highest zone is some distance from the tower (Department of Health, 2000). This kind of knowledge would enable the community groups to participate as equal interlocutors in a debate between their local MP and the mobile phone company. Undoubtedly, people are likely to ask questions that will explicitly show that they have a deep understanding of the issue. For example, their knowledge of the radiation zones can help them to contradict a possible company's claim that there is no cause for alarm as the school is far away from the transmitting antenna. As a result, the company would take them seriously, irrespective of their age or their social background.

In addition, local community groups would be less effective if they did not know some things about the way a mobile phone operates. Therefore, they should know that cell phones emit radio waves that travel through the air from a cell tower to the mobile phone and back again. Radio waves are a kind of radiation that is used by many other devices; a microwave oven is an example (Young et al., 2004). This knowledge would help people to demystify the transmitting antenna. It is certain that they would not treat it as a 'killer device' which could destroy their life. Their knowledge that radio waves are used in several other ways in their daily life, such as for example in the operation of the T.V., would help them deal with the problem on a correct basis, without any exaggerations. Nevertheless, it is likely that people need to question the certainty with which the cell phone company argues that the antenna is safe. Knowing that a cell tower is more than necessary for the phone's operation could make them have a much more critical and careful attitude in weighing up the company's assertions. Moreover, by knowing that the radiation travels through all directions, they would understand that irrespective of what the company may claim, it is impossible to protect yourself when you are outdoors. Inevitably, your brain will absorb some proportion of it.

Finally, it would be also useful for local community groups to be aware of some specific issues concerning the nature of science and the ethics that are often connected to real-life dilemmas. In particular, they should know that scientific knowledge in this area is characterized by uncertainty (Reiss, 2015). Even if it is proved that the heating effect of the absorption of microwaves is very small, no one can really ensure that it is completely harmless for our health. According to the scientific model, after microwaves pass through the human body, they are absorbed partially by the bones and partially by the brain. As a result, the brain is warmed. It is these effects of brain warming which are still unknown in the scientific community. Some evidence about this issue is used in teaching materials. The 'Ideas and Evidence Science Pack' is an example (Pupil Researcher Initiative, 2004). This pack includes information that shows that even if scientific research has shown that mobile phones do not cause brain tumors, there are individual cases that indicate that a relationship may exist between mobile phones and health problems. Therefore, no scientist can state with certainty the exact effects of radiation on the human body. Although the scientific community has constructed a very well-designed model about radiation, it is far from being in a position to answer any question regarding this issue. A number of questions concerning radiation, such as the long-term consequences of the absorption of microwaves,

are still inevitably unanswered (Gavrilas et al., 2022). In addition, people should bear in mind that we are the first generation that uses mobile phones daily and, as a result, there is no data concerning the consequences of this habit. Actually, the only thing that the scientific community can do nowadays is to estimate, as much as possible, the risk of using mobile phones and living near cell towers. As a result, regardless of the evidence that the mobile company will provide to verify its assertion about people's health living close to a transmitting antenna in a densely populated area, people can oppose companies' assertion knowing that it is impossible for someone to maintain that he knows exactly the consequences.

Research Question 2: Which places in the world have made the cell phone controversy headline news

It is a fact that socio-scientific issues often extend to sharp conflicts that arise between big companies and the public about the radiation of cell towers. Such companies have a solely profitable way of action that often makes them, due to controversial interests, not consider any other environmental or health factors. As a result, people often stand against them. On the altar of profit, companies may not adequately consider the population density, and the existence of hospitals, schools, and parks in the area where they plan the installation of transmitting antennas. As a result, it is quite likely that a number of citizens will react against them. Many times, the media have given attention to such issues. Several recent examples are coming from America, India, the United Kingdom, and Pakistan with petitioners who oppose the installation of cell towers in their residential areas. In San Francisco, California, there is an ongoing struggle of residents who fight against the installation of cell towers in several residential areas throughout the years. Some indicative examples are in North Beach (https://www.change.org/p/at-t-stop-new-cellphone-towers-in-north-beach-san-francisco-for-our-health) where a telecommunication company is expecting to install 9 new antennas on the rooftop of a medical center. In Candlestick Point, the same company wants to install a cell tower close to a residential area (https://www.change.org/p/san-francisco-planning-commission-change-at-t-cell-tower-installation-near-your-home), and right now in Sugarloaf Mountain Road, the same company wants to build a cell tower extension and add 15 antennas and radios in a fenced-in area close to residents' properties (https://ehtrust.org/strong-opposition-to-cell-tower-extension-on-sugerloaf-mountain-road-in-california/). In all the above cases residents of the areas start petitions gathering signatures against an American multinational telecommunication company, AT&T, wheeling out environmental, health and economic arguments. It's been years now that the locals postpone a lot of these installations proposing new locations that meet the requirements and they keep fighting with the support of a nonprofit organization, Environmental Health Trust (EHT) that guides them through the process (https://ehtrust.org/action-steps-on-cell-towers-near-homes-and-schools/).

Some more examples are coming from different areas of India on the same matter. Residents from Abhay Khand 3 very recently protested against a mobile tower installation continuing a fight that started a year ago, when the tower was initially installed. They argue that it is put in the middle of a footpath, very close to their residential area, threatening their health, and the property value of the area (The Times of India, 2022). Another group of people in Ludhiana protested some months ago about the same issue blocking the commute of a national highway. The protesters are against the installation of a mobile tower on private property, claiming health issues for the residents. The

installation was stopped so that the protest would end (The Tribune, 2022). Another case with an ongoing petition and 125 signatures so far is in Chennai (https://www.change.org/p/department-of-telecommunications-egmore-chennai-tamil-nadu-600008-petition-against-cell-tower-installation-in-residential-area). The petitioner argues against the installation of another cell phone tower wheeling out points inconsistent with the environmental protection rules as well as health implications.

Similar protests are seen very recently in the United Kingdom. In Westgate-on-Sea there was a public meeting in August to discuss worries about the siting of a 20ft cell tower to be installed next to St Saviour's junior school (The Isle of Thanet News, 2022). A petition followed the meeting that numbers 735 signatures so far. Likewise in Bristol, residents and their dogs protested against a 24.16m high tower, with a 14m x 8m footprint and a 2.5m high compound (Knowle West, 2022), which is planned to be installed in Redcatch Park. Their petition numbers 3888 signatures against the tower installation so far. It is worth noting that the first petition focuses on the health implications of having a cell tower so close to a school and to care homes, even if the implications are still unclear. The second petition focuses mainly on the aesthetic dimension and the environmental implications of precious green open spaces.

The lack of state policy for installing cell phone towers often blocks the petitions and protests from having results (The New Indian Express, 2019), but this is not always the case. According to Dawn, an English newspaper in Pakistan, in 2019, the Peshawar High Court (PHC) imposed the removal of 20 mobile phone base transceiver stations (BTS) from the provincial capital's densely populated areas, around schools, hospitals, and parks (Dawn, 2019). The decree was a result of a resident's petition about the adverse impact of BTS on human health and a report from the Environmental Protection Agency (EPA) about the presence of BTS near educational institutions, health facilities, mosques, and residential areas in the provincial capital.

Discussion

As is portrayed above, people should have different kinds of knowledge in order to be in the position to participate in debates about socio-scientific issues. Initially, they should have a basic knowledge of the scientific facts which are concerned with a specific issue. This would help them acquire a deeper understanding of the ideas which are involved in this issue. Apart from scientific knowledge, people should be familiar with the nature of science and ethics. Indeed, they should have a basic idea about the characteristics which govern scientific research. This would help them use scientific models in order to explain data and distinguish whether such data is reliable or not. Moreover, their knowledge about the uncertainty which exists in a specific science area can make them question statements of absolute safety. In addition, people should be aware of the technology which is involved in a socio-scientific issue. This knowledge would enable them to participate as equal interlocutors in debates, as they would be able to point to views that will explicitly show that they have a deep understanding of the issue. Moreover, people should be familiar with the policy directives in this science area. Indeed, the knowledge of the regulations existing in a specific area can help them to deal with a socio-scientific issue in a more effective way. Finally, regarding the ethical aspect, it is important for people to realize that they have to be united and take an active role in social issues. Along this line, they can see

themselves as decision-making citizens who can use science to determine the consequences of different courses of action (Ottander & Simon, 2021).

Nevertheless, in real life there are several other things which actually determine how people act in issues with a scientific dimension. Personal commitments play a crucial role in the way people deal with socio-scientific issues. This is clearly demonstrated in the issue of mobile phones. Specifically, while adults and teenagers seem to hold negative feelings about the health hazard effects of radiation, they don't adopt a protective stance against it. That is, they avoid turning off cell phones during sleeping, they do not keep the devices at a distance from their bed throughout the night and they generally prefer to hold the phone close to their head during a voice call instead of using headphones (Gavrilas et al., 2022). This inconsistency between the attitude of the individuals and their behavior may stem from the fact that cell phones often act as a lifestyle choice. People desire to keep constantly in touch with their friends and strengthen their bonds with them via sending text messages or calling them at any time during the day. From this perspective, mobile phones give them the opportunity to have a better social life. Another explanation could be the intention-behavior gap and that those who don't act upon an issue are the 'inclined abstainers' who cause the gap (Sheeran & Webb, 2016). According to Sheeran and Webb (2016), the intention's realization depends on a lot of factors and is more and more likely to become active when the person *initiates, maintains, and closes the goal pursuit*. Furthermore, there is research that shows that when the health consequences are long-term and probabilistic, people tend not to act upon them (Rehfeldt & Tyndall, 2022). Unfortunately, in many cases, teenagers get addicted to cell phones, which leads them to constant and steady use of them far beyond any limit or health consideration (Jun 2016; Pendse & Zagade, 2014).

Additionally, people will likely continue using mobile phones to facilitate and secure their work purposes. It is a fact that many people use them at work. Directors of big companies want to know exactly what happens in different branches at any time and mobile phones totally help them to achieve this goal. Moreover, workers regularly need to co-operate with each other even if they are long distance. Therefore, it is pretty often for employers to provide mobile phones to their employees to increase their company's productivity. The people in the trade also use mobile phones daily to facilitate their purposes. Furthermore, the use of mobile phones is often necessary for security reasons. We sometimes need to call for help during emergencies, and mobile phones are the best way to do it.

Judging from the above, different kinds of knowledge, apart from scientific facts, such as the nature of science and the ethics that are connected to real-life dilemmas, are necessary for someone to deal with a socio-scientific issue. The school curriculum should consider this diversity of knowledge. Drawing from constructivist theory, it should consider pupils' ideas and move towards a science curriculum that would be strongly related to their everyday life (Boilevin et al., 2022; Ravanis, 2022). This curriculum would equip students with the appropriate tools to understand the world around them and cope with many issues they face in their daily lives. Furthermore, it would give them the basic knowledge which would enable them to be effective citizens in the future. Undoubtedly, being on the threshold of the

21st century, researchers and pioneers of the Science Education field could work along this line and contribute to this goal.

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