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Using cell phones as an educational resource in the teaching and learning of natural sciences: possibilities and challenges

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ABSTRACT

Technologies have now become part of people's daily lives, especially the youth who is in constant contact with technological devices, such as cell phones. To keep up with the changes society has been facing, schools and teachers are called to update their pedagogical practices, in this case, by inserting these devices into the educational process. Based on a qualitative approach to research, this study aimed to identify methodological experiences in which the cell phone was used as a pedagogical resource in the teaching and learning of natural sciences in the final years of elementary school, analyze how it was used and verify both the positive and negative aspects of such experiences. The data collection was carried out through a systematic mapping of all investigations conducted in the last ten years (2010 to 2020), using the search engine Google Scholar, and the bibliographic databases CAPES/MEC Journal Portal and Scientific Electronic Library Online (SciELO). A significant number of research studies focusing on the diverse uses of the cell phone in science classes was found, suggesting positive results. The results indicate that this mobile device has the capacity to serve as a great ally of teachers given its didactic-pedagogical potential in the process of teaching and learning natural sciences.

KEYWORDS: Science Teaching. Teaching and Learning. Pedagogical Resources. Use of cell phones.

1 INTRODUCTION

Information and communication technologies (ICT) have deeply transformed society; as a consequence, the various segments of society, including the educational sphere, require transformations. Among the age groups, young people and adolescents are the most involved with ICT - especially with mobile and wireless information and communication technologies (MWICT) - through the use of their mobile devices and various applications (DOURADO *et al.,* 2014).

Despite the technological advances, many teachers keep working under a traditional model of teaching, in which they develop monotonous and decontextualized classes for their students. Under this scenario, they face new technologies, especially cell phones, as a threat to teaching or as a problematic gadget that brings distraction and causes problems at school (OLIVEIRA, 2015). Similarly, some teachers were reported to lack familiarity in using this technological device, thus feeling insecure when asked to use it as a pedagogical resource in their classes (CAMPOS; SOUZA; MATOS, 2021).

Despite the negative views on the use of cell phones in the classroom, scholars such as Gadotti (2019) and Ribas and Galvão (2015) argue that new technologies, including the mobile device, present a series of resources that can bring more dynamism to the teaching process, offering the teacher some tools, not always available in schools, necessary for the development of didactic activities. Therefore, assuming the school as a space for providing education and information, school agents must rethink the practice of coercion regarding the use of MWICT by the students and instead take advantage of the potential of this technology in promoting the teaching and learning[1] of the school subjects.

In addition, as Campos, Souza and Matos (2021) assert, both ICT and MWICT were proved to be instrumental in the context of the COVID-19 pandemic, serving as the main means of communication between people, an integral part of remote jobs, and an asset to the promotion of remote teaching in Brazil, when face-to-face classes had to be turned into remote classes, also known as emergency remote teaching (ERT).

When it comes to teaching the natural sciences, the use of ICT and MWICT is reinforced because it presupposes dynamic methodologies, such as the use of didactic resources that favor students' learning, which enable them to participate in scientific and technological discussions. Thus the urgency to have school administrators and teachers review their position regarding the use of technologies to teach science, especially the cell phone, since it has been proved to be an accessible tool among students (GOUVÊA; PEREIRA, 2015).

Given the aforementioned problematization, this investigation was motivated by the following questions: has the cell phone been used as a pedagogical tool that helps natural sciences teachers and/or researchers in the process of teaching and learning sciences? If so, in what ways and what results have been achieved?

In order to answer these questions, this study aimed to identify methodological experiences in which the cell phone was used as a pedagogical resource in the teaching and learning of natural sciences in the final years of elementary school, as well as to analyze how it was used and verify both the positive and negative aspects of such experiences.

The following sections bring the theoretical framework that based this research, its methodological procedures, the results achieved, the scholarly discussions proposed and the conclusions reached.

2 INFORMATION AND COMMUNICATION TECHNOLOGIES IN SCIENCE TEACHING

Information and communication technologies (ICT) have a great influence on people's lives, being present in all spheres of society, including education. In this particular matter, ICT can attract students' attention and arouse their interest towards the learning process, often facilitating the understanding of school subjects. As a consequence, we argue that schools need to rethink their practices as to include ICT in their pedagogical repertoire. According to Dourado *et al.* (2014, p. 364), "science teachers should value them [ICT] as a pedagogical resource and use them in order to contribute and assist in the process of knowledge construction"[2]. However, some teachers are still reluctant to use them in their classes.

In addition to ICT, mobile and wireless information and communication technologies (MWICT) have become more and more present in the daily lives of adolescents and young people. Among the MWICT, Bento and Cavalcante (2013, p. 114) state, "we cite the cell phone, a popular device, with applications that can be used in the classroom as a pedagogical resource". These technologies can be used as pedagogical tools to facilitate the process of teaching and learning of science in the school classroom.

According to Oliveira (2015), as cell phones are an instrument used by students in their daily lives, they can serve as a motivating resource that helps students construct knowledge, also mediated by their teachers. Campos, Souza and Matos (2021) also argue that if students like to use cell phones, they should be adopted as a didactic-pedagogical resource given their several tools that may help make the teaching and learning of a given school subject more dynamic.

In a similar vein, the United Nations Educational, Scientific and Cultural Organization (UNESCO) encourages the use of mobile phones in the classroom for pedagogical purposes. In fact, the organization launched a document called Policy Guidelines for Mobile Learning (PGML) in 2004, which highlights the benefits of introducing the cell phone as a pedagogical tool and suggests some policies that would enable governments to introduce this technological tool in the classroom, such as teacher education programs. According to UNESCO, mobile devices serve as learning facilitators, bridging formal and non-formal learning experiences. "Using a mobile device, students can easily access supplementary materials in order to clarify ideas introduced by a classroom instructor" (UNESCO, 2014, p. 21).

With the COVID-19 pandemic, the cell phone has become the main pedagogical tool used by teachers and students in remote classes across Brazil, which contributed to avoid the interruption of classes due to the social isolation policy. In some educational institutions, for example, teachers began to communicate with their students through groups created on *WhatsApp*, in which they would send activities, audios with directions, and even online classes recorded on *Google Meet* in virtual classrooms, promoting real-time interaction between teachers and students (CAMPOS; SOUZA; MATOS, 2021).

In this context, the cell phone is regarded as “a more easily accessible means of communication and that its applications can contribute to building on existing knowledge” (GOUVÊA; PEREIRA, 2015, p. 42). Bento and Cavalcante (2013, p. 115) also argue that “through the ease of using different applications on the cell phone, the possibility of its use in the classroom is clear to us: from the calculator to the access to virtual libraries”.

All things considered, we corroborate the argument scholars such as Dourado et al. (2014), Oliveira (2015) and Ribas, Silva and Galvão (2015) have advanced, which affirms that the cell phone has a great potential to contribute to the process of teaching and learning natural sciences if used by teachers in their classes. Therefore, it should be used in science classes.

> Given the fact that students who are immersed in technology are more curious and always in search of new sources of learning, cell phones can serve as an ally of teachers and no longer a mere object which causes problems and must be overcome at school (GOUVÊA; PEREIRA, 2015)

With regard to science classes, cell phones facilitate the use of applications with various functions, including virtual laboratories of chemistry, physics and biology, all easily accessible and possible to be downloaded to mobile phones with compatible operating systems. Such possibility sponsors an extensive pedagogical support in science teaching and contributes to students' learning if we take into account that many schools do not have science laboratories.

Despite all the possibilities and benefits of using a mobile phone in the process of teaching and learning, it is deemed prohibited in some schools (OLIVEIRA, 2015; GADOTTI, 2019; CAMPOS; SOUZA; MATOS, 2021). Such resistance may result from the fact that teachers and school administrators are unable to see its potential as a pedagogical resource, giving space to prohibitions and conflicts towards its adoption as a pedagogical device in educational processes. Thus, “among the challenges related to the use of cell phones as pedagogical resources in school, [one lies] in training education professionals [...]" (GOUVÊA; PEREIRA, 2015, p. 46).

The difficulty students face to have internet connection, or even to own the device itself, adds to the list of challenges reported by scholars and teachers. During the COVID-19 pandemic, these particular problems revealed to be critical impediments to the students' active and full participation in school remote activities. In fact, some schools do not have internet connection and/or when they do, it is not available to students due to a wide social inequality in Brazil “in relation to broadband internet access, especially outside urban centers” (FONSECA, 2013, p. 177). Thus, school administrators need to pay attention to their students' needs and contexts. The aforementioned PGML, formulated by UNESCO (2014), alert governments to offer all students, deprived and privileged, access to mobile learning, so as to guarantee equal access to technology for all persons.

3 METHODOLOGY

The investigation at hand, qualitative in nature, used bibliographic research to collect data. Through a systematic mapping, we gathered articles, theses and dissertations[3] found on Google Scholar, CAPES Journal Portal and Scientific Electronic Library Online (SciELO). These web search engines/databases were

chosen because they are widely used in Brazil and cover several journals that address topics related to education and science teaching.

For the systematic mapping, the keywords "*Science" "teaching*" were used along with: *"mobile phone", "cell phone", "smartphone"* and *"application"*. The words were written inside quotation marks and separated by a single space, with no use of search operators, such as "*AND*" "*OR*". To filter the results, we applied the criteria: 1. Interventions which took place in the last ten years (2010 to 2020); 2. Interventions which used cell phones as a pedagogical tool in the teaching and learning of natural sciences in the final years of elementary school; 3. Articles/Research produced in Brazil and published in Portuguese. After using the keywords in alternate groups and applying the first criterion, a more rigorous analysis of the research pieces found was made based on the second and third criteria.

The data were analyzed in three stages, according to Bardin´s (2016) content analysis. Firstly, the titles and abstracts of the studies which met the criteria were read; secondly, the material found were organized and then analyzed according to categories elaborated both *a priori* and *a posteriori*; thirdly, inferences about the results of the investigation were made.

The *a priori* categories were created based on the assumptions advanced by the scholars who compose our theoretical framework (DOURADO *et al.,* 2014; UNESCO, 2014; GOUVÊA; PEREIRA, 2015; OLIVEIRA, 2015; RIBAS; SILVA; GALVÃO, 2015; CAMPOS; SOUZA; MATOS, 2021), with the goal to analyze the positive aspects about the use of cell phones in the classroom. They are organized with the letter P standing for positive and numbered from one to seven, as presented in Table 1.

Table 1 - A priori categories on the positive effects of using cell phones in science classes.

Categories	Description
P1	Motivating students to learn
P2	Encouraging student participation
P3	Favoring and promoting student-student and student-teacher interaction
P4	Introducing contents in a more attractive and playful manner
P5	Building on existing knowledge
P6	Facilitating the process of teaching and learning
P7	Promoting students' construction of knowledge

Source: Research data (2021).

4 RESULTS AND DISCUSSIONS

Data are presented in tables, following the order of the criteria and the objectives listed for the present research.

4.1 Pedagogical interventions that used cell phones as a didactic tool in science teaching

Table 2 presents the quantity of studies found in each search engine/bibliographic database related to the keywords used for the bibliographic research.

Table 2 - Quantity of articles found on the databases.

	Databases		
Keyword Groups	Google Scholar	CAPES Journal Portal	SciELO
"science" "teaching" "mobile phone"	5.560	62	0
"science" "teaching" "cell phone"	12.100	169	0
"science" "teaching" "smartphone"	15.600	360	0
"science" "teaching" "application"	17.600	787	1

Source: Research data (2021).

As shown in Table 2, several studies were found in the search. However, of these, only 22 studies met the criteria adopted by this investigation (see Table 3).

Table 3 - Investigations which met the criteria.

Code	Titles	Type	Database
T1	Smartphones and applications: pedagogical tools in the teaching of natural sciences (GONÇALVES, 2015).	Capstone project - Lato sensu graduate course	Google Scholar
T2	Smartphones as a pedagogical tool in the classroom (KIRSCH, 2015).	Capstone project - Lato sensu graduate course	Google Scholar
T3	Turn on (off) that cell phone, you brat! Smartphones as a mini-laboratory for teaching science (ROCHA et al., 2015).	Article	Google Scholar
T4	The cell phone as a pedagogical tool: repercussions on science learning from a video production project (ROCHA, 2015).	Capstone project - Lato sensu graduate course	Google Scholar
T5	Cell phone applications' potentialities for science teaching: paths taken at the school Maria Aparecida Nunes in São Joaquim/SC (MADEIRA, 2016).	Capstone project - Lato sensu graduate course	Google Scholar
T6	The use of mobile technologies in science teaching: an experience on the study of coastal ecosystems situated in the Atlantic	Article	Google Scholar/CA

	Forest in Southern Espírito Santo (SANTANA et al.., 2016).		PES Journal Portal
T7	Cell phone as a pedagogical resource to motivate science teaching in adult education (TAKAHASHI, 2016).	Article	Google Scholar
T8	The use of information and communication technology (ICT) as a resource in the process of teaching and learning science (ZANI; STRIEDER, 2016).	Article	Google Scholar
T9	DoctorBio: a case study on the use of augmented reality resources in the teaching of biological sciences (ARAUJO et al.., 2017).	Article	Google Scholar
T10	Digital technologies in physics teaching: using cell phones to approach content related to velocity and speed (SANTOS et al.., 2017).	Article	Google Scholar
T11	Contemporary technologies as pedagogical resources for science classes (SCHNORR; RODRIGUES; ISLAS, 2017).	Article	Google Scholar
T12	Cell phones as a pedagogical tool in science classes (FARIAS, 2018).	Capstone project - Undergraduate Program	Google Scholar
T13	Applying animation to science teaching using the school garden (FERREIRA; MELO; ALVES, 2018)	Article	Google Scholar
T14	The creation of web videos to teach science (GOMES, 2018).	Capstone project - Lato sensu graduate course	Google Scholar
T15	Mobile entertainment devices as educational tools in elementary school of the Brazilian system 'colégio militar' (SILVA, 2018a).	Capstone project - Lato sensu graduate course	Google Scholar
T16	The QR Code and other smartphone resources as tools to approach contents related to the phylum Arthropoda (SILVA, 2018b).	Capstone project - Undergraduate Program	Google Scholar
T17	Immersive experiences: a study on the impact of virtual reality in science teaching (BARBOSA et al.., 2019).	Article	Google Scholar
T18	Research-based science teaching and QR Code use in an environmental recovery area (DUQUE et al.., 2019).	Article	Google Scholar
T19	Use of the QR Code application in science teaching (COLMAN, 2019).	Capstone project - Lato sensu graduate course	Google Scholar
T20	Science teaching, augmented reality and sophus app: an experience in a rural school (Assú/RN) (MORAIS, 2019).	Master´s Thesis	Google Scholar

T21	The use of a mobile application to teach science in a rural school in Pontal do Paranapanema – SP (BRITO, 2020).	Master´s Thesis	Google Scholar
T22	Contributions to science teaching in the final years of elementary school through a collaborative production of animations (PINTO, 2020).	Master´s Thesis	Google Scholar

Source: Research data (2021).

Table 3 shows a significant number of studies that demonstrate the possibility of using the cell phone as an educational tool for teaching and learning content related to natural sciences in different ways and contexts. The results underline how cell phones, when used appropriately in the classroom, can favor students' learning in basic education. As well established in the literature (UNESCO, 2014; GOUVÊA; PEREIRA, 2015; OLIVEIRA, 2015; BENTO; CAVALCANTE, 2013), mobile devices can contribute to motivate students in their learning processes and help them construct knowledge, given the fact that they are well-known instruments found in students' everyday lives.

Most of the studies found, however, are linked to undergraduate and graduate courses at universities and federal institutes of education. Table 3 shows two capstone projects for undergraduate programs, seven capstone projects for lato sensu graduate courses, three master's theses and ten articles, in which the origin of the course and/or institutions involved in the research is not clear.

These results are not deemed as negative. Instead, the fact that universities and institutes invest in research that can demonstrate the use of cell phones as a powerful tool for teaching and learning natural sciences is considered of utmost importance. The benefits of these studies need to reach schools nevertheless, since many school administrators and teachers still resist the adoption of this mobile device as a pedagogical tool in the educational environment (CAMPOS; SOUZA; MATOS, 2021; OLIVEIRA, 2015; GOUVÊA; PEREIRA, 2015).

4.2 Analysis of the ways the cell phone was used in pedagogical interventions to teach natural sciences

Table 4 presents the ways the cell phone was used during the pedagogical interventions under scrutiny and lists the codes of all investigations that fit into these categories. The analytical categories were elaborated *a posteriori*, based on the data found in the studies.

Table 4 - The ways in which the cell phone was used as found in the literature.

Categories	Description	Quantities	Codes
W1	The cell phone was used only to access applications	8	T1; T3; T5; T9; T10; T17; T20; T21;
W2	The cell phone was used to create audiovisual content (photos, videos and editing)	5	T4; T8; T13; T14; T22;

W3	The cell phone was used in various ways through different software	9	T2; T6; T7; T11; T12; T15; T16; T18; T19;

Source: Research data (2021).

According to Table 4, eight studies fell under category W1 (mobile/application), which corroborates the findings by Campos, Souza and Matos (2021). In their research, the authors argue that students can use their cell phones to download applications that favor working with school contents.

Among the findings identified in the 22 titles, T5 highlights that "it was an interesting discovery, because, according to the students, they only used applications for games and music and did not know applications suited for studying classroom-related subjects" (MADEIRA, 2016, p. 21). Therefore, the mobile phone, along with different applications, can help teachers and students in their processes of teaching and learning, especially when taken in an informed way in the classroom (GOUVÊA; PEREIRA, 2015).

Confirming this function, the researcher who authored T21 conducted experiments and built a virtual water cycle terrarium using an application. The ones who authored T3 and T10, on the other hand, reported that the cell phones allowed students to conduct physics experiments. With this goal, students used the applications their devices held, such as calculators and timers, in addition to others that were installed for such activity. Finally, they calculated the average speed traveled by the students. These reports point to the instrumental use of cell phones emphasized by scholars such as Ribas, Silva and Galvão (2015), Gouvêa and Pereira (2015) and Campos, Souza and Matos (2021).

The studies T9 and T20 showed the mobile phone being used to handle augmented reality (AR) applications. Whereas T9 used the application *Aurasma* to address content related to biology, such as cells, T20 used the application *Sophus* to present the systems of the human body in 3D. Unlike the previous research pieces, T19 used Virtual Reality (VR).

With regard to category W2 (cell phone/audiovisual content production), five investigations were included. In T4, T8 and T14, students engaged with filming, image capturing and video editing in order to produce documentaries and videos using their cell phones. T13 and T22, on the other hand, demonstrate research in which students produced animation videos with the technique *Stop Motion*. With their smartphones in hand, students were able to capture images, organize photos in sequences and produce animated videos, addressing the content studied.

This particular result confirms Bento and Cavalcante´s (2013) research finding: the mobile phone can be used as a pedagogical resource in various ways, including for research, as it allows access to virtual libraries, and for the production and dissemination of knowledge through videos.

The last category, W3 (mobile/various ways/different software), holds nine investigations. While T6 reports that mobile phones "[...] acted as instruments for identifying fauna and flora through the use of application, besides serving for registration [...]" (SANTANA *et al.*., 2016, p. 2234), T2 and T11 used the *Bluetooth* wireless technology present in mobile phones. In the latter case, T2 used the device for internet search and T11 used *Bluetooth* to help students transmit and share images of cells amongst themselves, as well as to send a song related to the

content being studied. In addition, the smartphones allowed students to play the song at hand.

T7 and T12 used the cell phone to perform activities through the use of applications such as *WhatsApp* and *Bluetooth*, and for research, filming, photos, audio, among other school activities. According to Takahashi and Camas (2016, p. 6), authors of T7, "some activities were created with the goal of using the different resources found available on mobile phones, as they serve as a tool for pedagogical support, in their relation to the content being taught in science classes".

T16, T18 and T19, finally, used the application *Qr code* on the cell phone to create codes containing information about the content previously studied, which were later made available for reading. T19 specifically had students to use the application *Pl@ntNet* for identifying plants scientifically, aiming to contribute to students' learning of this school content. In their words, “in a new stage of the research, the students, using their cell phones, photographed the selected specimens depicting the entire plant, details of its trunk, leaves, flowers and fruits when present” (COLMAN, 2019, p. 28).

The data demonstrate the numerous possibilities the cell phone holds to concentrate various resources—such as the internet, camera, calculator and others—in the same device, facilitating its use in the classroom and contributing to the process of teaching and learning science (RIBAS; SILVA; GALVÃO, 2015; BENTO; CAVALCANTE, 2013; GOUVÊA; PEREIRA, 2015).

4.3 Positive aspects on the use of cell phones in natural sciences classes as found in the studies

Table 5 shows the categories created *a priori*, based on the theoretical framework of this research. They shed light on the positive aspects concerning the use of cell phones in the classroom. It is worth noting that several works fell into more than one category.

TABLE 5 - Positive aspects of using cell phones in science classes.

Categories	Description	Quantities	Codes
P1	Motivating students to learn	18	T1; T2; T3; T4; T5; T6; T7; T8; T9; T10; T11; T12; T14; T16; T17; T18; T19; T21
P2	Encouraging student participation	12	T1; T2; T3; T4; T5; T10; T12; T16; T19; T20; T21; T22
P3	Favoring and promoting student-student and student-teacher interaction	10	T1; T2; T4; T5; T9; T10; T12; T15; T20; T21
P4	Introducing contents in a more attractive and playful manner	12	T1; T2; T5; T6; T7; T9; T10; T12; T14; T18; T19; T21
P5	Building on existing knowledge	3	T5; T8; T12
P6	Facilitating the process of teaching and learning	19	T1; T2; T4; T5; T6; T7; T8; T9; T10; T12; T13; T15; T16;

			T17; T18; T19; T20; T21; T22
P7	Promoting students' construction of knowledge	10	T1; T3; T4; T5; T6; T10; T12; T14; T17; T21

Source: Research data (2021).

As presented in Table 5, 18 studies were classified under category P1 (Motivating students to learn), for they presented the cell phone, with its resources, as a motivator for students' learning processes. To cite an example, let us consider T6. In this research, students showed great interest “in using mobile technologies in learning situations, [...] which reinforces a possible productive articulation among technological resources in the processes of teaching and learning science” (SANTANA *et al.*, 2016, p. 2234).

Given the data, we argue that mobile devices, such as cell phones, hold potential for encouraging students to learn if such devices are connected with the content being studied (GOUVÊA; PEREIRA, 2015). Smartphones, for instance, "can give students greater flexibility to move at their own pace and follow their own interests, potentially increasing their motivation to pursue learning opportunities." (UNESCO, 2014, p. 15). Similarly, the cell phone can be used in different contexts, thus acting as an instrument that allows students' processes of constructing knowledge to occur (OLIVEIRA, 2015).

In category P2 (Encouraging student participation), 12 studies were found. To begin with, T12 states that " the use of cell phones in the classroom has become a channel of communication and expression in face of the activities presented to students [...] which greatly contributed to the success of the activities designed by the teacher” (FARIAS, 2018, p.11-12). T19 reports that "not only have students' interest and participation in the activities proposed in science classes increased, but students' behavior has also significantly improved" (COLMAN, 2019, p. 37). All in all, we conclude that the device fostered students’ active participation during classes, promoting positive results.

About this, Campos, Souza and Matos (2021, p. 91) remind us that the “[...] school, in its curriculum, should consider the contexts in which its students participate, so that they feel valued and can actively participate in their own learning”. From this, one can infer that the cell phone, being part of students' daily lives, should be used to motivate them to participate in class and, consequently, understand the scientific concepts addressed.

In category P3 (Favoring and promoting student-student and student-teacher interaction), ten studies were found. T12, for instance, argued that ”much more than a pedagogical space, the use of mobile phones can serve as a space for interaction, allowing students to share their ideas responsibly, making a critical analysis of what they read and what they write" (FARIAS, 2018, p. 13). Similarly, T1 described that "the students were excited by the activities that promoted group interaction and they learned using a technology which was both familiar and of interest to them” (GONÇALVES, 2015, p. 44).

These reports suggest that the appropriate use of cell phones in the classroom can foster interaction among students—through group activities—and between students and teachers. As Ribas, Silva and Galvão (2015, p. 15) contend, the mobile phone with its technological convergence “[...] makes teaching practices more

interactive, provides students with an experience of reality, and expands mediation possibilities for teachers". All this for a small cost, since the resources can be found in the cell phones owned by the students and their teacher.

Category P4 (Introducing contents in a more attractive and playful manner) had 12 studies listed. According to Araujo *et al.* (2017) who authored T9, mobile phones helped students and teachers engage with the school content in an attractive and fun way, making classes livelier. The study conducted by Santos *et al.* (2017, p. 219), T10, corroborates this finding. In their perspective, "the mobile phone allowed teachers to introduce the content in the environment to which students feel attracted and comfortable".

Such data indicates, as Campos, Souza and Matos (2021) illustrate, that the mobile device is an attractive tool that most students have and like to use. Therefore, teachers should consider the use of cell phones in their classrooms, so that their lessons are interesting and interactive and can favor meaningful learning.

In category P5 (Building on existing knowledge), three studies were listed. In one of them, T12, the use of the mobile phone was reported to be a methodological resource which "was very good because it was considered a novelty and a tool which is in constant use by students, especially in what concerns filming and photographs—applications that will further enrich their knowledge" (FARIAS, 2018, p. 9). In T8, a student commented that technological resources foster the evolution of knowledge through interesting research (ZANI; STRIEDER, 2016).

Given these reports, the use of cell phones in the classroom as a pedagogical resource was confirmed to favor students' intellectual and social development. In addition, they reiterate the importance of teachers to be willing to plan moments for the pedagogical use of the cell phone, which may allow students to discover and expand their knowledge (GOUVÊA; PEREIRA, 2015).

Category P6 (Facilitating the process of teaching and learning) showed 19 studies which presented the mobile phone as a facilitator of the process of teaching and learning, being the category that accommodated the largest number of research articles. In T5, Madeira (2016, p. 30) assessed that "compared to previous years, the study of the cells, and thus students' learning, was not as successful as when we used the app *Cell World* to show the organelles in 3D animations".

T12 reported that "[...] the use of cell phones in the classroom served to have students awaken their taste for science and that this device is a tool that promotes teaching and learning in a dynamic and engaging way" (FARIAS, 2018, p. 3). Adding to that, T18 argued that "[...] when the teacher comes up with an activity which is meaningful to their students and demands the use of their cell phones, the lesson is taught in a more relaxed way and the technological tool helps in the teaching and learning process" (DUQUE *et al.*., 2019, p. 156).

Once again, studies demonstrate that new technologies should be seen as resources that facilitate the educational process and, therefore, ought to be part of the pedagogical resources of educational institutions. This way, mobile phones can and should be used by teachers and students worldwide to perform routines, such as accessing information and promoting learning.

In the last category, P7 (Promoting students' construction of knowledge), ten studies were found. T4 reported on how the production of videos facilitated the students understanding of the content being studied, as well as how "they felt confident in producing their own knowledge, considering that they themselves conducted research [...] and found pertinent information for the construction of documentaries" (ROCHA, 2015, p. 40). In the case of T19, the author emphasized that students "also recognized that they need to have responsibility, commitment and compromise to transform information into knowledge" (COLMAN, 2019, p. 42).

In the same lines, T3 explained that "it is possible to make these devices a mini-laboratory for scientific experiments, which in addition to enhancing meaningful learning, it can transform experience into a mechanism that leads students to reflect on what they found". Rocha *et al.* (2015, p. 41) also argue that

> Mobile communications technologies [...] are part of the students' cultural identity and enable them to develop their own scientific experiences autonomously, taking the knowledge built in the classroom outside the school environment, allowing the dissemination of their learning, as well as the dissemination of their experiences on social networks.

Based on the results found, we argue that the use of the cell phone as a pedagogical tool in the classroom can positively contribute to the teaching and learning process involving both students and teachers. With regard to the former, it promotes their motivation to learn the school content, fosters interaction among themselves and between them and the teacher, builds on their existing knowledge and can favor their knowledge construction. As for the latter, it facilitates the approach of the curricular content in a more attractive and playful way, engaging students throughout their learning process.

4.4 Negative aspects on the use of cell phones in natural sciences classes as found in the studies

Regarding the negative aspects, 11 studies (T1; T5; T7; T8; T10; T15; T17; T18; T19; T21; T22) reported the difficulty of accessing the internet in schools and students who did not have a smartphone to perform the proposed activities. Another negative aspect identified in five studies (T1; T10; T18; T19; T20) was the fact that students got distracted when they had to use their cell phones during the lessons.

In this regard, Fonseca (2013) highlights the great inequality in Brazil when it comes to internet access, especially in places such as peripheries and rural areas. On the one hand, despite the fact that many people own smartphones, their internet access can be very limited. Also, as shown in the studies, not all students have a mobile phone. On the other hand, as Campos, Souza and Matos (2021) denounce, many schools do not yet have internet access or such access is not shared with the students.

Aware of this reality, UNESCO, through the Policy Guidelines for Mobile Learning (UNESCO, 2014), calls the attention of governments to increase the learning possibilities for students who have a mobile device, as well as to ensure chances of mobile learning for those who do not have mobile phones. In the same

lines, Gouvêa and Pereira (2015) highlight that governments should develop public policies that provide digital inclusion in schools.

5 FINAL REMARKS

This research sought to identify interventions that portrayed teachers and/or researchers using the cell phone as a pedagogical resource in the classroom. In addition, it aimed to analyze the ways the cell phone was used in natural sciences classes, and verify the positive and negative aspects of using it during the teaching and learning process. As for the first goal, the results demonstrated a satisfactory volume of studies on the theme, since a reasonable amount of publications that address the use of cell phones in the classroom was found.

As for the second, the results pointed to several positive aspects regarding the use of the cell phone as a pedagogical tool for the process of teaching and learning natural sciences. Among its uses, one can cite the approach and production of science-related content and the conduction of scientific experiments, all through diverse applications. These findings point to the conclusion that the mobile phone is an important tool and can serve as an ally of teachers once they consider its great didactic-pedagogical potential.

Notwithstanding, negative aspects were also reported. Some teachers, for instance, observed their students getting distracted when using their cell phones during science classes, which may have happened due to the teacher's lack of experience in handling the device and using it during the lesson. When this was the case, we recommend that teachers take part in in-service and pre-service teacher education programs that deal with technologies and especially mobile phones in the classroom, so that they can safely plan and give classes using this tool. Another negative aspect reported was the issue of digital exclusion, still much present in the country, which discourages the use of cell phones during classes.

A final interesting finding points to the fact that most of the selected studies are interventions of academic nature applied by researchers. Although we believe that there are interventions focused on the use of cell phones as a didactic resource in the classroom advanced by school teachers, we could not find them published. The lack of this type of research, conducted by school teachers, demands further investigation.

O USO DO CELULAR COMO RECURSO DIDÁTICO NO ENSINO-APRENDIZAGEM DE CIÊNCIAS DA NATUREZA: POSSIBILIDADES E DESAFIOS

RESUMO

As tecnologias passaram a integrar a vida cotidiana das pessoas na atualidade, principalmente dos jovens que estão em constante contato com os aparelhos tecnológicos, como o celular. Assim, a escola e os professores devem renovar as suas práticas pedagógicas inserindo esses aparelhos no processo de ensino-aprendizagem. O presente trabalho teve como objetivos identificar na literatura, experiências metodológicas que utilizaram o celular como recurso pedagógico no ensino-aprendizagem de Ciências da Natureza, nos anos finais do Ensino Fundamental, analisar as formas de utilização do celular nessas intervenções e conferir os aspectos positivos e negativos dessas experiências. A pesquisa pautou-se na abordagem qualitativa. A coleta de dados foi realizada por meio de um mapeamento sistemático de trabalhos desenvolvidos nos últimos dez anos (2010 a 2020) e teve como instrumentos de coleta as plataformas de pesquisa: Google Acadêmico, o Portal de Periódicos da CAPES – MEC e a *Scientific Electronic Library Online* (SciELO). Foram encontrados um número expressivo de trabalhos de pesquisas realizados por professores/pesquisadores, utilizando o celular de diversas formas, através de intervenções pedagógicas em aulas de Ciências nas escolas, apresentando resultados bastante positivos. Assim, pode-se concluir que esse dispositivo móvel tem a capacidade de ser um grande aliado do professor na sala de aula diante do seu grande potencial didático-pedagógico no processo de ensino-aprendizagem de Ciências da Natureza.

PALAVRAS-CHAVE: Ensino de Ciências. Ensino-Aprendizagem. Recursos Didáticos. Uso do Celular.

NOTES

1. The term teaching and learning presented throughout the article is based on the Freirean pedagogy, which assumes the reciprocal and intrinsic features of any educational process. According to this pedagogy, teaching is not valid when there is no learning, because “whoever teaches learns in the act of teaching, and whoever learns teaches in the act of learning". (FREIRE, 1996, p. 23).

2. All quotes and titles were translated from Portuguese to English by the authors.

3. Master's theses and doctoral dissertations were included in the research under two reasons: the average time to publish research in some journals and the goal to cover as many studies as possible, as to give visibility to such a relevant topic nowadays.

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