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BioIntegrada Game Application: An Instrument for the Systemic Teaching from Cells to the Environment

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ABSTRACT

Background: Biology contents in high school are worked in a fragmented way, and in excessively theoretical and expositive classes, but game apps appear as tools with high playful potential. **Objective:** To identify the contributions of BioIntegrada in the construction of the integrative perception of the contents of the cell and the environment. **Design:** Qualitative approach and action research method. **Setting and participants:** 40 students enrolled in the 2nd grade of high school at a state public school in the municipality of Milhã, Ceará, Brazil. **Data collection and analysis:** We used audio recordings and questionnaires with closed and open items and analysed the textual information with the Iramuteq software. **Results:** BioIntegrada is composed of eight phases, addressing issues of cellular structure, tissues, organs, human body systems, the cycle of worms, scales of ecological organisation and daily actions. By validating the app, we found that the students improved their theoretical knowledge and argumentative level, starting to relate abiotic and biotic factors with the constitution of living beings and deepening socio-environmental discussions of the web of humans and nature relationships. Furthermore, the students evaluated the app positively; 95% liked using it and considered it a facilitator of learning; 85% agreed that it is intuitive and its phases are stimulating. **Conclusion:** BioIntegrada facilitated learning contents, promoted the integrated perception of the human body and the environment, and was evaluated as good by the students.

Keywords: Game application; Natural sciences; Biology teaching; Critical environmental education.

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Aplicativo de jogo BioIntegrada: um Instrumento para o Ensino Sistêmico da Célula ao Meio Ambiente

RESUMO

Contexto: Os conteúdos de biologia no ensino médio são trabalhados de forma fragmentada e em aulas excessivamente teóricas e expositivas, mas os aplicativos de jogos surgem como ferramentas com elevado potencial lúdico. Por isso, investigamos se o app BioIntegrada seria uma boa ferramenta para trabalhar conteúdos de Biologia de forma sistêmica. **Objetivo:** Identificar quais são as contribuições do BioIntegrada na construção da percepção integradora dos conteúdos de célula a meio ambiente. **Design:** Abordagem qualitativa e método da pesquisa-ação. **Ambiente e participantes:** 40 alunos do 2^0 ano do ensino médio de uma escola pública estadual do município de Milhã, Ceará, Brasil. **Coleta e análise de dados:** Utilizamos gravações em áudio e questionários com itens fechados e abertos, cujas informações textuais foram analisadas no software Iramuteq. **Resultados:** O BioIntegrada é composto de oito fases, abordando assuntos de estrutura celular, tecidos, órgãos, sistemas do corpo humano, ciclo de verminoses, escalas de organização ecológica e ações cotidianas. Com a validação do app constatamos que os alunos apresentaram melhoria no conhecimento teórico e no nível argumentativo, passando a relacionar fatores abióticos e bióticos com a constituição dos seres vivos e aprofundando discussões socioambientais da teia de relações homem e natureza. Os estudantes avaliaram positivamente o app, 95% gostaram de usá-lo e o consideraram facilitador da aprendizagem; 85% concordaram que ele é intuitivo e suas fases são estimulantes. **Conclusão:** O BioIntegrada facilitou a aprendizagem dos conteúdos, promoveu a percepção integrada do corpo humano e ambiente e foi bem avaliado pelos estudantes.

Palavras-chave: Aplicativo de jogo; Ciências da natureza; Ensino de biologia; Educação ambiental crítica.

INTRODUCTION

Brazilian students still see scientific content as something distant from their experiential reality, apparently without any direct influence on it (Nascimento, Fernandes, & Mendonça, 2010). In part, this results from decontextualised classes and textbooks that focus on defining concepts, which are worked in an isolated and fragmented way, idealising an abstract student, disregarding time and space, and ignoring the actual student with their collective and individual experiences (Compiani, 2007). That is why it is important that contextualised teaching considers students' real and lived situations at the centre of the educational process (Santos, 2007).

The biological constitution of the human being and how it relates to the environment is a theme of biology teaching with great potential for contextualisation. The issues are especially relevant in a scenario where human actions result in increasing environmental degradation (Souza & Andrade, 2014), which makes it necessary for us to (re)build the feeling that we are beings that belong to nature and, as such, its destruction affects us (Sauvé, 2005).

Given this context, we developed and used in class a game app called BioIntegrada, aimed at systemically working on contents related to the human body and the environment, covering i) morphological structuring of the human being: cells, tissues, organs, and systems; ii) human participation in worm cycles; iii) levels of ecological organisation and iv) reflections on how human actions impact the environment. These contents are usually fragmented in basic education textbooks (Lopes & Vasconcelos, 2012), making it difficult to contextualise and integrate the pedagogical practices of the biology themes addressed in class.

The combination of the app and didactic game tools was based on the assumptions that games entertain, motivate, and facilitate learning (Tarouco, Roland, Fabri, & Konrath, 2004) and the application is a type of information and communication technology that has great pedagogical potential (Barbosa Neto & Fonseca, 2013; Dourado, Souza, Carbo, Mello, & Azevedo, 2014). The game app also meets the National Common Curricular Base (Base Nacional Comum Curricular - BNCC) recommendation, in the general competence five for basic education:

> Understand, use, and create digital information and communication technologies in a critical, meaningful, reflective, and ethical way in the various social practices (including school ones) to communicate, access, and disseminate information, produce knowledge, solve problems and exercise protagonism and authorship in personal and collective life. (Brasil, 2018, p. 9)

Therefore, our research question deals with the need to identify whether BioIntegrada is a tool that facilitates the systemic teaching of biology matters related to the structuring of the human body and relationships with the environment, including encouraging observations and reflections on how anthropic actions impact the environment.

THEORETICAL BASIS

High School Legislation

Here, we highlight some general provisions for basic education included in the law of guidelines and bases of education (Lei de Diretrizes e Bases da Educação - LDB) n. 9.394/96. Article 22 states that "Basic education aims to develop the students, assuring them a common education indispensable for the exercise of citizenship and providing them with the means to progress in work and further studies" (Brasil, 2016).

Education aimed at building active citizenship is when the individual is aware of their rights and duties to exercise the tense experience of democracy, with Paulo Freire as one of the main inspirations (Gadotti, 2000). Through this kind of education, citizens effectively participate in political decisions that affect them. Moreover, it provides the necessary conditions for an individual's inclusion in the public space (Ribeiro, 2002).

Article 35 of the LDB emphasises that secondary education will have

> III - The improvement of the student as a human person, including ethical education and the development of intellectual autonomy and critical thinking.
> IV - Understanding the scientific-technological foundations of production processes, relating theory to practice when teaching each subject (Brasil, 2016).

The Brazilian National Common Core Curriculum (Base Nacional Comum Curricular- BNCC), regulated in article 26 of No. 9.394/96, defines high school learning rights and objectives according to the guidelines of the National Education Council [Conselho Nacional de Educação] (Brasil, 2018). This standardising document presents ten general basic education competencies. For the area of natural sciences and its technologies in high school, the guidelines indicate competencies and skills to be achieved through objectives that stimulate the analysis and interpretation of natural phenomena, aiming to develop of actions to improve socio-environmental conditions and encourage the dissemination of scientific knowledge in technological means, including the use of communication media.

Throughout the BNCC text, we come across passages that deal with the use of technologies, the importance of an education that encourages facing challenges, critical thinking, and the ability to make decisions. We give an example as follows:

> In the new world scenario, recognising oneself in one's historical and cultural context, communicating, being creative, analytical-critical, participatory, open to the new, collaborative, resilient, productive, and responsible requires much more than the accumulation of information. It requires the development of competencies to learn to learn, to know how to deal with increasingly available information, to know how to discern and be responsible in digital culture contexts, to apply knowledge solve problems, be able to make independent decisions, be proactive in identifying the data of a situation and seek solutions, and live with and learn from differences and diversities. (Brasil, 2018, p. 14)

For Natural Sciences, according to Franco and Munford (2018), those aspects have the potential to deconstruct merely content-based teaching, with the proposal of an articulated scientific knowledge capable of developing a critical sense and subsidising tools to think about the phenomena that surround us. However, the BNCC refers to the traditional, clinging to fragmented scientific knowledge. As Franco and Munford (2018) discuss, this document presents a list of contents that guide teaching practice, emphasising conceptual aspects but not favouring their interconnection. In addition, several analyses of this document show the political meaning, as highlighted by Branco et al.,

> Despite being a normative document for basic education, the BNCC is more directed towards a curricular reorganisation, under the aegis of the influence of the business community and the interests of international bodies..., large companies, non-governmental organisations and philanthropic institutions acted, as "partners and collaborators", moulding the curriculum and/or teaching to conditions that do not reflect the commitment to solving problems, which involve inequalities in the right to learning - as recommended by the BNCC. (White, White, Iwasse, & Zanatta, 2019, p. 273)

It is important to emphasise the amount of criticism regarding the BNCC and high school reform. Zanatta, Branco, Branco, and Neves (2019) report that the curriculum reform and organisation proposed by the BNCC prioritises the labour market to the detriment of social and humanistic issues, which tend to lose the space conquered in recent decades. This position goes against the discourse of education for citizenship, many times discussed in educational legislation, and hurts teacher autonomy.

Facilitating Strategies for Teaching and Learning

There is a broad consensus on the need for scientific education to prepare citizens for decision-making (Praia, Gil-Pérez, & Vilches, 2007). Therefore, education must move toward the critical and reflective formation because

> Depending on how the educational process unfolds in the teacher-student-knowledge triangulation, it can also lead to intellectual development and increase the student's understanding of the natural or socially created environment in which they live, and thus act in a non-coercive way, contributing to the formation of a critical/reflective individual. (Tavares, 2016, p. 323)

The educational process has been changing and generating new needs. For this reason, Silva and Navarro (2012) stated that teachers need to reflect at all times on their practice based on solid theoretical grounds to encourage the exercise of autonomy and criticism, deviating from the principle that exposing the student to the content is enough for their formation (Abrahão, & Merhy, 2014). Education must be able to trigger a vision of the whole (Fornaziero et al., 2010) and enables the construction of networks of social change with the consequent expansion of individual and collective consciousness (Mitre et al., 2008).

However, working on scientific content with young people who live in a dynamic society with numerous distractions is a great challenge in the school environment. For that, digital information and communication technologies (DICTs) can assist students' achievement in school learning. Knowing the potential of technologies, different forms of knowledge construction, new perceptions, and pedagogical possibilities become pulsating (Soares & Istoe, 2015). However, these resources alone do not guarantee systemic and critical learning. Teachers are important actors in the teaching and learning process (Cavas, Cavas, Karaoglan, & Kisla, 2009).

If the DICTs are used to emphasise content, they will bring good results in gaining knowledge (Dourado, Souza, Carbo, Mello, & Azevedo, 2014). Other strategies used with good results to stimulate student protagonism, the development of citizenship, and scientific education have been games with didactic purposes. Games can represent a valuable pedagogical resource, as they entertain while motivating, facilitating learning and increasing the ability

to understand what has been discussed (Tarouco, Roland, Fabre, & Konrath, 2004).

> In general, the students do not understand the teacher's scientific language easily during lectures, and games can promote discussions in which interactions between the teacher's and students' languages occur, facilitating the establishment of meanings common to both and, consequently, the learning of the scientific concepts addressed in the games. (Focetola et al., 2012)

In a study in which Barbosa Neto and Fonseca (2013) developed a game app to work on mathematics, they described that most students (87%) agreed that they were able to identify in the game the contents the teachers worked on in classes, and all agreed that they felt motivated as they progressed through the stages. Huizenga, Admiraal, Akkerman, and Dam (2009) showed that a mobile game-based learning strategy was highly effective for high school student learning.

Gamification increases student motivation, promoting positive changes in relation to an effective learning process (Kiryakova, Angelova, & Yordanova, 2014). Therefore, in possession of the evidence, it is clear that educational games are an essential means to assist with the teaching and learning process (Silva Neto, Santos, Souza, & Santos, 2013). Thus, the use of the DICTs and didactic game applications are tools with high potential to arouse the interest and participation of young students in classes, facilitating the teaching and learning processes of scientific concepts and content and allowing an integrated approach to content, despite its fragmented approach in textbooks or other teaching handbooks.

Systemic Understanding of the Human Body to the Environment

The crisis of the human beings-nature bond occurs due to the loss of the human capacity to identify what connects them to the animal, to what is alive, to nature (Tres, Reis, & Schlindwein 2011) because humans are part of nature and, on the other hand, nature produces hominisation (Morin, 2005). However, human beings need to continually produce their very existence (Saviani, 2015), and for that, instead of adapting to nature, they try to adapt nature to them, that is, to transform it. This transformation causes much damage to nature and human well-being.

> Thus, the great challenge for today's society is the search for new forms of relationship between human beings and nature and, consequently, between human beings. A nature in which humans recognise themselves as an integral part and are responsible for it. And education certainly has something to do with this issue, especially if one considers that current education is still strongly marked by a vision of science that partly consists of the contrast between human beings and nature. (Ramos, 2010, p. 87)

This dissociation between humans and nature or humans and environment occurred through a historical context of the construction of capitalist society, so that:

> Capitalism subsidised by science and modern technology has consolidated processes of dehumanisation of nature and denaturing of humans, elaborated by the stages of construction of modern science, based on rationalism, confirming reciprocal externalities between humans and nature, i.e., humans understood as a being excluded from the concept of nature, being above it due to the superiority of their rational property, legitimising the degradation of nature, perceived merely as an inexhaustible source of the same resources, since nature was considered to have mechanisms and gears, just like machines, which enabled it to reproduce itself eternally in a homogeneous way. (Soares, Navarro, & Ferreira, 2004, p. 43)

In an attempt to lead our society to reflect on the integration of the individuals and the environment, education must play the role of the organiser and producer of the culture of a people (Dias & Dias, 2017). Also, to conceive a new society/nature relationship, it is necessary to think about educational practices that consider the environment in local, regional, and global aspects (Mariano, Scopel, Peixinho, & Souza, 2011). Therefore, we must overcome technical and instrumental education and promote changes, having the integration of content as a foundation (Guimarães & Inforsato, 2012) and considering the social reality of those involved (Fornaziero et al., 2010).

This is not an easy task because, as Silva and Schnetzler (2006) point out, teacher training in Biology is based on in-depth knowledge of scientific content to the detriment of pedagogical issues, promoting a simplistic view of the teaching profession. However, thinking about the training of teachers as educators means having as a reference the idea of totality (environmental,

political, pedagogical, social, scientific, etc.) in the diversity of those areas (Guimarães & Inforsato, 2012). In this sense, Araújo and França (2013) state that academic training is directly related to teaching practice so that if it contemplates principles of critical education, praxis has excellent chances of doing so, too.

Permeated by those thoughts, we built the theoretical framework of this investigation that enabled us to plan, act, and reflect for and in the daily pedagogical practice toward a biology teaching committed to acquiring scientific, social, and environmental knowledge in an integrated and contextualised way. To do so, we selected the human body and environment theme as a study model, produced a game app, and evaluated its use in a high school class.

METHODOLOGY

This research is a pedagogical intervention, guided by a qualitative approach, with mixed data analysis (qualitative-quantitative) to evaluate the pedagogical use of the BioIntegrada game app. We chose qualitative research because, although we use combined elements of data analysis, the subjectivity that cannot be translated into numbers was present, guiding our options of classroom interventions and interpretations of the results in all phases of the pedagogical intervention research, which we defined as the one that:

> […]involves the planning and implementation of interferences (changes, pedagogical innovations) – aimed at producing advances and improvements in the learning processes of the subjects who participate in them – and the subsequent evaluation of the effects of those interferences. (Damiani, Rochefort, Castro, Dariz, & Pinheiro, 2013, p. 57)

Forty students enrolled in the 2nd grade of a public state high school in the municipality of Milhã, Ceará, Brazil, participated. Milhã's predominant vegetation is the Caatinga, and the region's economic activities are linked to deforestation and fires. The area for cultivation corresponds to 72.5% of the municipal territory; agroforestry systems with cultivated area, crops, and animal grazing represent 17.8%, and the area of natural vegetation assigned as permanent preservation or legal reserve corresponds to only 11.9% of the territorial extension of the municipality (IBGE, 2017). Moreover, only 21.7% of households had adequate sanitation, and 12.2% of households did not have a bathroom (IBGE, 2010).

The investigation was carried out between 2018 and 2020 and was approved by the Ethics Committee in Research with Human Beings of the Universidade Estadual do Ceará (CEP-UECE) with opinion number 3.542.107. The methodological description of the research steps will follow the axes of production, use, and pedagogical evaluation of the game app.

Production of the BioIntegrada App

The game app was developed through the flutter framework tool, aiming at the multiplatform development the tool offers and the way flutter works since, despite making hybrid applications that can run both on the Android and IOS, they are compiled natively, which leaves the application with a better response as it uses native resources of the platforms. For the app, we also used the Git as a form of versioning and the GitHub for code repository. BioIntegrada is available for Android devices in the app store Play Store, at the link: https://play.google.com/store/apps/details?id=com.biointegrada (Figure 1).

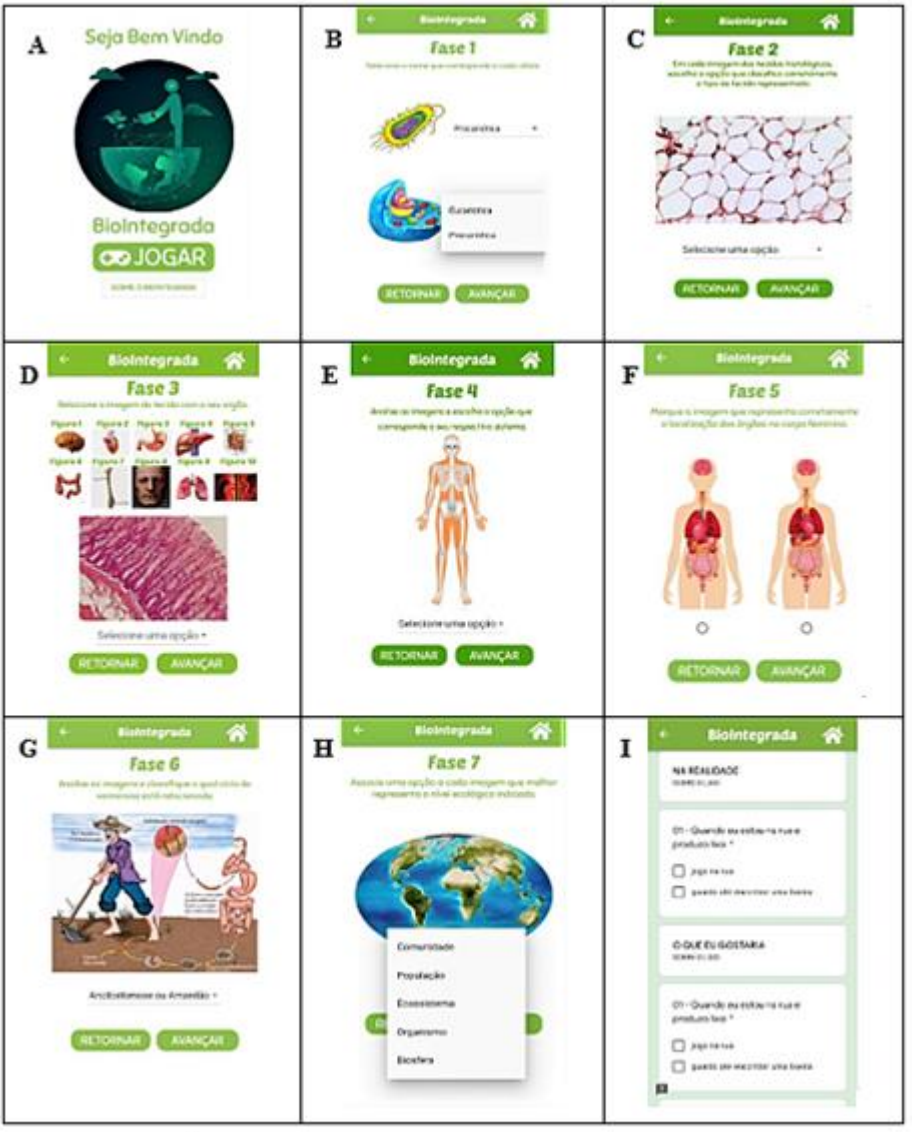
The structuring of the contents in a sequenced way and ending with reflections of our actions in everyday life can foster student involvement and stimulate the development of critical thinking and the ability to understand integrated biological concepts and their relationship with the local environment. In this sense, in the SD button available on the app's home screen, there is a proposal for a didactic sequence to be used in class that is structured for eight class hours (Figure 1A).

The game has eight phases aimed at correctly analysing and relating the structures and advancing to the next challenge. Phases one through five range from the microscopic to the macroscopic level: cells – tissues – organs – systems – organism (Figure 1B-F)). Phase six refers to some cycles of worms that the human being hosts and shows this organism's integration with the local environment. Phase seven refers to the hierarchy of life at the ecological level: population - community - ecosystem - biosphere. And finally, phase eight involves completing a questionnaire (Figure 1 G-I).

Each class works on one or more phases of the game. It is only possible to access the phase that is being addressed after overcoming the elapsed challenges, always allowing a resumption of the previous contents. At the end of the game, we have phase eight for completing a questionnaire, whose purpose is to stimulate reflection on human actions in everyday situations (Figure 1 I).

Figure 1

BioIntegrada Game Application.
(https://play.google.com/store/apps/details?id=com.biointegrada)



Use and Pedagogical Evaluation of BioIntegrada

To facilitate the availability of the app to be installed on the mobile phones, organise the pairs during classes, and carry out the activities in class, we chose two students as monitors. They created a WhatsApp group with the title "Projeto BioIntegrada", with only the participants of the study and the teacher engaged.

To collect data about the pedagogical validation of BioIntegrada, we used audio recordings of the classes and information computed in two types of questionnaires: i) diagnostic questionnaire and ii) opinion questionnaire. The diagnostic questionnaire consisted of four open items to know the students' perceptions of the relationship between human beings and nature in two moments: before and at the end of the didactic sequence. From now on, we will call them pre-classes and post-classes questionnaires. The second questionnaire was designed on a Likert scale to register the students' opinions about the use of the app. It was composed of nine questions related to easiness, tastes, and difficulties using the app.

We evaluated the textual information collected in both questionnaires through word cloud graphics and similarity analysis with the software *Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires* (Iramuteq). The word cloud is a lexical analysis that groups words and represents them graphically according to their frequency so that the most frequent words in the textual corpus appear larger and in central positions in the cloud. In turn, the similarity analysis also allows us to identify occurrences and connections between words, distinguishing common parts of a textual corpus (Camargo & Justo, 2013). The information on frequencies or percentages collected with the Likert-scale opinion questionnaire was represented in Excel graphs. Whenever necessary, we used excerpts from the students' answers to exemplify the results, with the anonymity of those involved maintained at all times.

RESULTS AND DISCUSSION

BioIntegrada was developed with the understanding that teaching scientific concepts to young people living in a society with numerous distractions is a great challenge in the school environment. Digital information and communication technologies (DICTs) are essential resources for students' achievement, involvement, and protagonism (Barbosa Neto & Fonseca, 2013). The DICTs proved to be even more indispensable during remote classes during

the Covid-19 pandemic. Those tools allowed motivation and collaboration in learning in emergency remote classes but can also be used for the same purposes for in-person or hybrid classes (Yates et al., 2020; Pereira, 2021).

In the group of DICTs, we can highlight the production, use, and pedagogical evaluation of apps, as experienced with Anato Mobile (Costa et al., 2016), with Bio Respiração (Santos et al., 2022), and with our BioIntegrada. We found that those applications for mobile devices, after pedagogical validation, facilitated the learning and teaching of school biology content, meeting the demands of an education connected with modernity. But, as Cavas, Cavas, Karaoglan, and Kisla (2009) and Dourado, Souza, Carbo, Mello, and Azevedo (2014) warn, teachers are indispensable actors and must be involved in all stages of implementation of those tools, ensuring that it is an advantageous approach to teaching practices in promoting the achievement of educational objectives. The DICTs do not dispense with the educator/student relationship in all its nuances, and with this understanding, we discuss the production and validation of the application in this research.

The operation of the BioIntegrada game consists of overcoming the challenges in eight phases, which present an increasing level of complexity, both in terms of cognitive knowledge and the organisation of living beings. Phase 1 with the challenge of differentiating cell types; phase 2 to identify human body tissues; phase 3 with the challenge of relating the tissue image to the organ; phase 4 to recognise human body systems; phase 5 has two screens, each containing two images of the human organism, and the challenge is to identify which figure has the correct position of the organs. These five phases work on the levels of organisation of the human body because we consider it important to deal with this theme initially and correlate it with discussions about the environmental issues proposed in the progress of the game in phases six to eight (Figure 1). Therefore, BioIntegrada functions to facilitate the teaching and learning of biological contents from cell to environment, collaborating with the discussion by Santos (2007), when he states that scientific education should enable the interpretation of the social role beyond knowledge of scientific information.

Moving on to phase 6, our challenge is to recognise, on seven screens, each containing a different cycle, some cycles of worms that humans host (Figure 1). The images were selected by being situations that most resembled the ones in the communities of the northeast region of Brazil, where the students participating in the research live. The types of worms presented in the app are commonly addressed in the textbook, but according to França, Margonari, and

Schal (2011), the contents on worms are presented in the textbook without establishing the relationship between health and the environment. We believe that the content of worms inserted in this sequence of steps in the app may encourage the users to relate those concepts. It may also enable them to associate the attitudes and consequences of human actions.

Phase 7 contains five screens and deals with the levels of organisation in ecology, and to contextualise this content, we used some sceneries and living beings from the Caatinga (Figure 1). For this structuring, we followed Fonseca and Caldeira's (2008) recommendations that the concepts related to the levels of organisation of Ecology must be addressed in an integrated way, avoiding fragmentation. And to help with this concept of integration, between the game's phases, dialogue boxes were placed to discuss in small texts the integration between the topics covered.

Phase 8 ends the game, and consists of a form entitled "my actions in everyday life" to be filled in as the last requirement to complete the game. This form is structured with questions in two sections: one refers to what the person actually does and the other to what he or she would like to do in relation to garbage, water, electricity, and lifestyle (Figure 1). For this proposition, understand that as human beings, we are affected by and affect nature (Dulley, 2004), therefore "[...] it is necessary to rebuild our feeling of belonging to nature, [...] be aware that through nature we reencounter part of our human identity, our identity as a living being among other living beings" (Sauvé, 2005, p. 317).

The validation of BioIntegrada took place with 40 students from the 2nd grade of high school arranged in pairs, 39 aged between 15 and 17 years and one was 18 years old. There was a predominance of females, corresponding to 57.5%, a trend that is currently maintained in the following levels of education, including undergraduate, master's and doctoral degrees (CAPES, 2017). Regarding the interest in using the app, 95% of the participants declared that they like it, corroborating the potential for the pedagogical use of this tool among young people pointed out by Sonego and Behar (2015).

The primary source of income comes from activities in agriculture, livestock, and agriculture (65% of families). It is also important to note that 50% of the class stated that their family's home is in the urban area and 50% in the rural area, which means that 15% of the families, even living in the urban area, move to work in the rural area. Only 35% of students declared that they are served by autonomous water and sewage service, and 65% do not have a water supply, using other sources such as weirs, wells, catchment basins, and

cisterns. Regarding basic sanitation, 52.5% said they did not have it, and 35% said they did not have public municipal garbage collection. This is a worrying scenario, as these are considered risk factors for the population's health. Studies such as those by Giatti, Rocha, Santos, Bitencourt, and Pieroni (2004), demonstrated, for example, a correlation between basic sanitation conditions and the prevalence of intestinal parasites and diseases such as schistosomiasis. This diagnosis was fundamental for the conduction of the content worked in the BioIntegrada game application with a phase designed to the cycles of worms in which the human being is a host, in addition to a final phase of daily actions, since:

> The relationships established with the student's daily life should allow giving meaning to the curricular content, bridging the gap between what is learned at school and what is done, lived, and observed on a daily basis [...] the teaching and learning processes must seek effective links with everyday life, however, they must overcome it, looking for an articulation between this daily life and the most conceptual and abstract levels of learning, in a permanent movement of action and reflection. (Kato & Kawasaki, 2011, p. 46)

The BioIntegrada app and the SD bring together an education proposal where scientific knowledge is articulated and contextualised to facilitate the relationship of scientific concepts with everyday phenomena and consequent decision-making, aspects defended by Franco and Munford (2018) as potent in the teaching of Natural Sciences. Moreover, the environmental contents of the proposal were also addressed from a critical perspective, understanding that this macro trend in the school universe should move towards a reflective and participatory posture, encouraging the practice of active citizenship (Jacobi, 2003).

The pedagogical intervention revealed that BioIntegrada provided the opportunity to learn about the structure and constitution of the human organism; at the same time, it promoted spaces for discussion about how this organism relates to the environment individually and collectively. For Silva and Campina (2011), these relationships are expressed by a web of interactions historically determined and composed of natural, social, and cultural elements. Given this, reflections on the integration of living beings and anthropic impacts were stimulated, understanding, as Loureiro (2006, p.7) postulates, that it is not appropriate to "talk about changes in behaviour without thinking about how

each individual lives, their context, and their concrete possibilities of making choices".

The students' perceptions about the relationship between human beings and the environment before and after the use of BioIntegrada, analysed through the word cloud resource, showed that: in the pre-class situation, the words "natureza", 'cuidar", "preservar" and "não" [nature, care, preserve, and not, respectively] were the most frequent (Figure 2A). Those words appeared in students' answers, for example: *"Since we are beings that can think, we must take care of what is ours in the best way"; "To care, take care of the greatest beauty and wealth of humanity"; "Nature is one of the greatest assets that human beings have, so our role is to care for, preserve, to receive all the benefits that it offers us"; "We must preserve nature as much as possible, otherwise, life may be extinguished"; "We must not deforest"; "We must not throw garbage in inappropriate places"*. Those answers demonstrate similarities with the assumptions of the pragmatic conception of environmental education, which, according to Layrargues and Lima (2011), was instituted in the Brazilian context in the 1990s and represents a derivation of the conservative conception linked to anthropocentrism adapted to the new social context, however with limitations on the reflections of social inequalities.

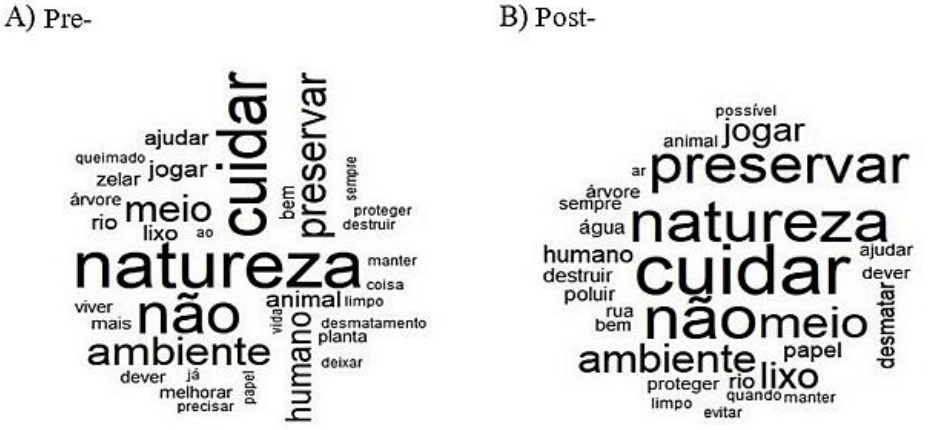
In the post-class situation, the words "cuidar" and "preservar" [care and preserve] had the number of citations increased, obtaining greater prominence in the word cloud (Figure 2B). These data reveal that some elements of the pragmatic conception of environmental education were still present in the students' responses, even after classes, with emphasis on the anthropocentrism and the vindictive nature of the pragmatic conception (see Silva & Campina, 2011). As an aspect of anthropocentrism, we highlight the passages in which students cite that: *"We must care for and protect nature so that we can have a better evolutionary process"; "The role of human beings in nature is to preserve and take care of what is ours". As examples of the law of action and reaction (vengeful nature) we took parts of the answers in which the student claims "[...] to be nice to nature so that it is also nice to us".*

However, in the post-class situation, care for nature and the preservation of the environment were also highlighted (Figure 2B), exemplified in excerpts such as*: "The majority, instead of helping to take care of nature, destroys it, what ends up causing a big problem for us, now, or even in the future"; "Protect and take care of nature, so that it does not end our lives and the lives of animals"; "[...] at each moment you can collaborate a little and this collaboration becomes great if the majority participates"*. Such excerpts

point to a conception of EA close to the critical political-pedagogical macrotrend because, as Silva and Campina (2011) and Layrargues and Lima (2014) point out, it is characterised by a change in behaviour that was previously carried out at the individual level and is now replaced by the formation of a culture of citizenship in which ecological, ethical, and social elements are present.

Figure 2

Students' perception of the role of human beings in nature



Concerning positive and negative actions, the theme "lixo" [garbage] was significantly highlighted in all analysed situations (Figure 3). In the positive pre-class actions, the words "não", "jogar", "lixo", "cuidar", "meio" and "ambiente" [no, throw, garbage, care, and environment, respectively] were highlighted (Figure 3A). In the post-class, these words continued to be stressed and "água" and "desmatamento" [water and deforestation] also appeared (Figure 3B). Those appearances certainly owe to the discussions about local socio-environmental issues carried out during the classes, as Milhã-CE has agriculture as one of the main economic activities, and the practices of burning and deforestation are usual to expand this activity. This discussion is vital mainly because, in Ceará, the levels of environmental degradation related to agriculture and livestock are increasing, as mentioned by Campos, Ferreira,

Coelho, and de Lima (2015), also impacting the process of desertification of the Caatinga (Souza, Artigas, & Lima, 2015).

Figure 3

Perception of human interference in the environment

Regarding the negative actions in the pre-class, the terms “lixo”, “jogar”, “queimado” and “animal” [garbage, throw, burned, and animal] were highlighted, the latter due to the hunting practice in the region (Figure 3C). In the post-class situation, the concern with “garbage”, “deforestation”, and “fires” [queimadas] continued; however, “water”, “pollution” [poluição] and “pesticides” [agrotóxicos] and “waste” [lixo] were also mentioned (Figure 3D),

revealing a greater repertoire of the negative interferences of the post-class compared to the pre-class.

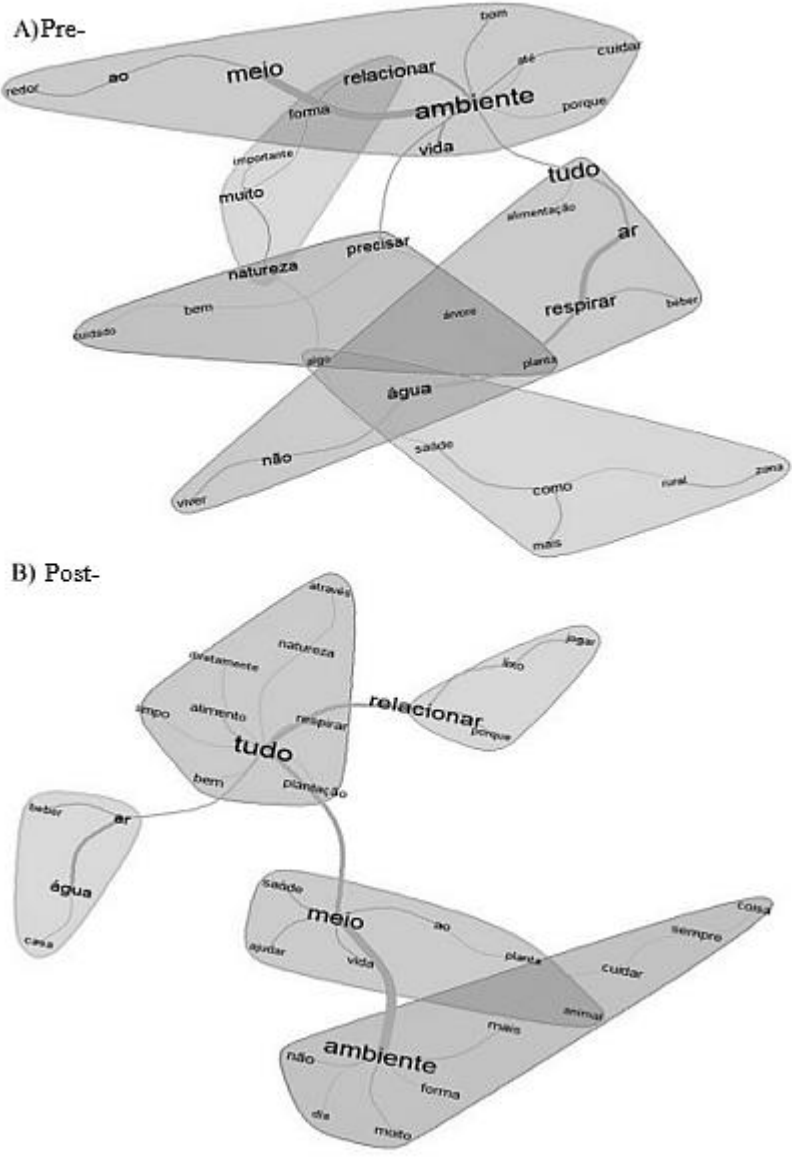
We consider it relevant that the students pointed out the issue of waste because, as Almeida, Santos Junior, Nunes, and Liz (2019) discuss, environmental imbalances are deeply related to inappropriate human conduct. In addition to economic losses, waste also causes serious impacts on natural resources. Pesticides not only poses risks to human health; it causes serious environmental problems ranging from improper disposal of packaging to severe damage to the balance of fauna and flora (Campos, Ferreira, Coelho, & Lima, 2015). It is crucil to contextualise because, as Sauvé (2005, p. 318) argues, "The place we live is the first crucible for the development of environmental responsibility, where we learn to become guardians, users, and responsible builders of Oïkos, our shared "life home"".

The students' perceptions about the relationship between the environment and human life, evaluated through similarity analysis, showed that the central words in the textual corpus were "meio ambiente" and "tudo" [environment and everything (Figure 4). From the central expression environment, the words "cuidado" e "vida" [care and life] were derived in the pre-class and "health and no" in the post-class. This demonstrates the strong relationship with health, taking into account that: "[...] the environment is not just the setting where the population lives, but in which their interactions and interrelationships take place, directly and indirectly impacting the health-disease process" (Bruzos, Kamimura, Rocha, Jorgetto, & Patrício, 2011, p. 464).

The lexicon "everything" in the pre-class has a connection with "plantas" and "alimentação" [plants and nourishment] (Figure 4A), but in the post-class the connections were with "plantação", "alimentação", "respiração", "limpo" and "natureza" [plantation, nourishment, breath, clean, and nature] (Figure 4B). Amplifications are present in answers of the type: *"In everything, without the environment, there is no way to have life, because we are dependent"; "The environment is involved in everything, in nourishment, in the air we breathe, in the water, when sleeping and waking up, nature is involved in everything"*. This perception of totality is in line with Suavé (2009) and Silva and Campina (2011), for whom relationships with the environment are complex social, historical, and emotional constructions.

Figure 4

Similarity analysis of the relationship between the environment and students' lives



During the classes, in addition to the biological content of the human body and the hierarchy of life, we encouraged discussions on how this content is related to local everyday issues. At those moments, we could identify the main deficiencies on the topics addressed, such as confusion in the definitions of viruses and bacteria, fungi and protozoa, and difficulty in recognising the macroscopic structures of the human body, such as the location of organs in the busts and anatomical images.

During the classes, the improvement in the learning of biological concepts and structures was noticeable, and the debates evolved into questions about how microscopic beings are related to human beings. The students grasped that *"Bacteria and fungi help in agriculture and improve food production"; "Micro-organisms can cause us diseases, but being in balance in our body, they can defend us against diseases"; "The decomposition process is important for everyone in the environment"; "Protozoa are involved in the digestion process of cows and the production of milk" and "Each living being has its role in nature, but if they get out of balance they can cause bad things"*.

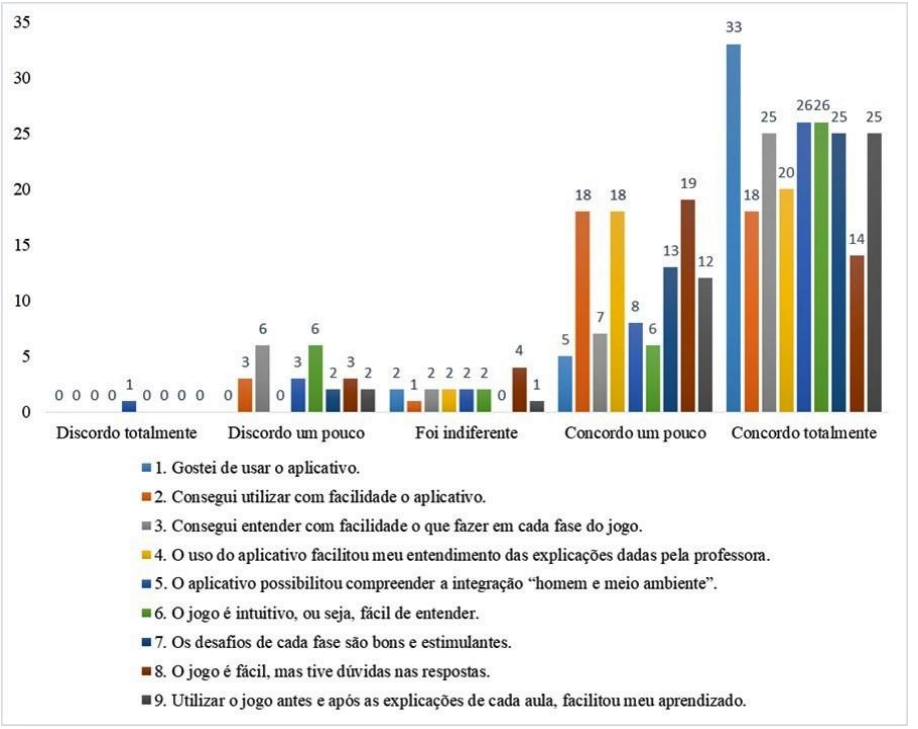
There were discussions on deforestation practices and inappropriate packaging disposal by local business people. They also said that those activities harm the environment with greater intensity when compared to family farming practiced in the municipality. In this way, a collective reflective and critical posture of reality was established, vital for the insertion of the citizen as a transforming agent of their environment, as defended by Freire (1987), Jacobi (2005), Silva and Campina (2011), and Layrargues and Lima (2014). Those results were significant to discussing at school the citizenship-oriented education defended by authors such as Freire (1997), Gadotti (2000), and Ribeiro (2002).

The students' opinion about BioIntegrada was expressed in high levels of total or partial agreement on all items (Figure 5), so that: i) 95% liked using the application (33 totally and five partially) and 90% were able to use it with ease; ii) 95% considered that the use of the application facilitated the teacher's explanations (20 fully agreed and 18 partially agreed; ii) 92.5% agreed that the strategy of using the game before and after the explanations of each class facilitated the learning of biological contents (25 totally and 12 partially); iv) 85% evaluated that the game facilitated the understanding of the relationship between human beings and the environment (26 totally agreed and eight partially agreed), while 2.5% (one student) totally disagreed, this being the only item marked with total disagreement; v) 85% considered that the challenges of

each stage of the game are good and stimulating; 80% were able to understand what to do in each stage of the game and 80% found the game to be intuitive.

Figure 5

Student opinion about the use of the BioIntegrada app, considering a maximum of 40 marks for each item



Therefore, according to the percentages obtained with the opinion of the students who collaborated with the research, we can consider that the BioIntegrada app has the potential to arouse students' attention when using the DICTs to work on the content, allowing new visions and encouraging protagonism in the construction of learning. Educators' evaluation of the pedagogical potential of applications is essential but equally important is the evaluation of the students, who have shown high levels of acceptance and

performance, results expressed in research with other apps (Costa et al., 2016; Pereira, 2021; Santos et al., 2022), as was registered with BioIntegrada.

CONCLUSIONS

Those results reveal that formal education can be carried out with the use of electronic games developed for this purpose. In the specific case of the BioIntegrada app, it can contribute to environmental education while teaching biological content and letting students have fun, increasing their interest and motivation in the subject. Evidence shows that the BioIntegrada app is a tool that facilitates the systemic teaching of biological matters related to the structuring of the human body and the environment.

Using BioIntegrada in class caused enthusiasm and provided greater student participation, encouraging cooperation between peers and highlighting students' skills in dealing with technological tools. However, using mobile phones in formal education requires teachers' attention, especially when developing strategies to reduce and/or avoid getting away from the class objectives. Another factor to be considered is the inclusion of students who do not have a mobile, which can be circumvented by organising students into teams so that they are not harmed by not having the device.

The BioIntegrada game pleased the students. Its use with the didactic sequence awakened students' perception of their environment, mainly when associating environmental balance with well-being and health. We also noticed the beginning of the deconstruction of the concept that only people who live in rural areas are subject to interaction with nature. However, we are aware that using the app alone has limitations in encouraging people to understand their surroundings and develop critical environmental education. Therefore, it is necessary to structure debates on the content covered in the app.

We recommend that the BioIntegrada app, alone or together with the SD "Human Being and Environment" [Ser Humano e Meio Ambiente], be done with the encouragement of didactic strategies where students can act in their communities for the development of an active citizenship.

AUTHORSHIP CONTRIBUTION STATEMENT

VMPM prepared the material, developed, collected, and analysed the data, and APS followed the entire process and contributed with directions,

material preparation, analysis, and writing. All authors discussed the results and contributed to the final version of the manuscript.

DATA AVAILABILITY STATEMENT

The data supporting the results of this study will be made available by the corresponding author, VMPM, upon reasonable request.

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