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Planning an interdisciplinary educational artifact: potentials, weaknesses and challenges

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ABSTRACT

Currently, there are concerns about the fragmented teaching of science. Thus, interdisciplinary teaching is assumed as a trend, capable of presenting students with a vision of the whole, closer to reality. In this sense, this article seeks to describe the planning of an interdisciplinary artifact designed to promote the articulation of knowledge from the Natural Sciences. It is an excerpt from a master's research, completed last year. It is a descriptive research, guided by the theoretical-methodological assumptions of Design-based Research. Here, the description of the process is specifically presented with regard to the following steps: formation of the design group; identification and analysis of the problem in the school context; analysis and search for solutions; construction and organization of the educational artifact. As a result, the organization and planning of an interdisciplinary work on the Radiation and Radioactivity theme is presented, highlighting the potential, weaknesses and challenges of the process. It is believed that this work can help researchers and professors who aim to carry out interdisciplinary projects and promote the articulation of knowledge in their practices. Furthermore, as much as this work deals with the disciplines of Natural Sciences, the way it was carried out can be replicated for articulation of concepts referring to other areas of knowledge, or even for the articulation between different areas of knowledge.

KEYWORDS: Natural Sciences. Design-Based Research. Interdisciplinarity. Articulation of knowledge. Teaching.[1]

INTRODUCTION

This article brings an excerpt from a master's research in Science and Mathematics teaching, carried out by the author Raquel Tusi Tamiosso - who also participated in the preparation of this article - during the years 2018 and 2019, whose general objective was to articulate the knowledge of Science of Nature through a Design-based Research. Concerns related to difficulties in articulating disciplines in the area of Natural Sciences, reported by teachers at a primary school, were the main motivations for carrying out the researcher's study. Teachers commented that the lack of articulation of the Natural Sciences sometimes makes learning difficult for students, who cannot connect the subjects they study.

The research problem that culminated this writing is highlighted: how to develop an educational artifact that promotes the interconnection between concepts of Biology, Chemistry and Physics? Here, in the introduction, the first step to seek a solution is presented: It was necessary to choose a school year of the school in which the research was carried out, in order to determine an integrative theme that would fit the curriculum provided for those subjects at their school level. We chose to work with the first year of high school, and the integrative theme chosen was Radiations and Radioactivity. From the integrated study of this theme, with the eyes of specialists (teachers of Chemistry, Physics and Biology) focused on it, planning and strategies were developed to articulate the knowledge involved.

Thus, the purpose of this article is to describe, specifically, the planning carried out to promote the articulation of the knowledge of the Natural Sciences. This planning will be described, in detail, from the moment the problem emerged in the school context, to the organization and elaboration of the interdisciplinary educational artifact, developed to be applied in the classroom, together with students. It is believed that the way in which the interdisciplinary artifact was elaborated can help other researchers and professors, who have the objective of carrying out interdisciplinary projects, in the articulation of knowledge and integrated activities between disciplines. Obviously, this work is specifically about the Natural Sciences, however, the methodological theoretical assumption used is universal, that is, it can contribute to interdisciplinary planning in any other areas.

Also in this article, the theoretical framework covers interdisciplinarity, due to the issue raised by the professors and which motivated the entire organization of the research. In addition, the Design-Based Research (DBR) is presented, as it acted as a theoretical methodological assumption, guiding all steps of this study.

INTERDISCIPLINARITY

Currently, Science is taught in a fragmented way, compartmentalized into separate disciplines that are generally not related to each other. Couto (2011) emphasizes that at the three levels of formal education, purely disciplinary education has become predominant. He also comments that organized and fragmented contents emerged from a didactic assumption and were divided into increasingly closed spaces of disciplinary specialties. On the other hand, the phenomena actually happen together, dynamically and concomitantly, different from the way they are taught at school. In this environment, it is taught in parts, in a fragmented way, in an attempt to make concepts more didactic, more understandable. However, authors such as Santos, Câmara and Fonseca (2018) emphasize that fragmented teaching sometimes makes knowledge distant from reality, as the relationship between the parties is not always clear to students, which makes learning difficult. Corroborating this idea, Gerhard and Rocha Filho (2012) argue that the contemporary scenario requires a complex view of the world, so that concepts are articulated, related to each other. Thus, there is a possibility for the student to see more sense in what he studies in different subjects, when he realizes that knowledge complements each other to explain situations in reality.

Lapa, Bejarano and Penido (2011, p. 2, our translation) state that

> Regarding to the Brazilian reality, we find an education historically marked by fragmented and disjointed curricula in which the various disciplines are studied in isolation. Reality is treated in pieces: pieces of Geography, pieces of Physical Education, pieces of History, pieces of Literature, pieces of Mathematics, making the educational process a solitary practice on the part of the teachers of each discipline. This view denotes a mistaken perception of reality, which is built interactively and constitutes a complex of connections between the different areas of knowledge, in their facets and dimensions.

International research and works attach relevance with regard to interdisciplinary approaches in teaching (BOSCH, 2020; CZERKAWSKI; SCHMIDT, 2019; STYRON, 2013; OKAMURA, 2019; POWER; HANDLEY, 2019; ASHBY; EXTER, 2019). In these works, there is an important question that the authors raise: the problems of the world are complex and, therefore, the knowledge of only one discipline is generally insufficient to solve them, or even understand them. It is necessary that the knowledge of the disciplines complement each other, provide support for each other, so that the view of a situation is total, and not partial. Czerkawski and Schmidt (2019) argue that in most universities there is a strong movement in support of interdisciplinary initiatives, but they emphasize that, despite this undeniable desire, it is a slow process to be implemented in its entirety. What can be said, based on the current literature, is that the efforts for improvements in education are increasing and pointing in the same direction: articulation of knowledge, integral education, interdisciplinarity, solving complex problems.

In the search to reduce the fragmentation of knowledge in teaching, interdisciplinarity presents itself as an alternative. Styron (2013, p. 47) states that "Since knowledge is not acquired in isolation, interdisciplinary education is an important tool in creating new ways of thinking and helping to connect fragmented knowledge in a coherent way". For Alvarenga et al. (2015, p. 63, our translation), interdisciplinarity

> [...] presupposes a new form of knowledge production aimed at complex phenomena. In its assumptions, it seeks to operate across disciplinary boundaries not only from theoretical, methodological and technological exchanges, but also by creating new languages and instruments, in addition to the commitment to (re)link knowledge generated by disciplinary thinking.

Augusto et al. (2004, p. 278, our translation) corroborate this idea, stating that "[...] interdisciplinarity is understood as the need to integrate, articulate, work together". Still, Bosch (2019, p. 33) argues that interdisciplinarity "[...] is understood as a depth of information, where two or more disciplines are integrated, focusing on the same real-world problem and solving its complexities through blending and linking of disciplines". It can be seen, therefore, that the authors do not talk about the exclusion of disciplines, nor do they argue about the possibility of extinguishing them, when adopting an interdisciplinary practice. What is recommended is the interconnection, the relationship, the articulation between them, so that students perceive the complementarities and, thus, acquire a vision of the whole, instead of receiving fragmented and disconnected information.

Corroborating this idea, Czerkawski and Schmidt (2019, p. 2) state that "Interdisciplinarity does not mean denying current disciplinary structures, but it instead requires a fine-tuned integration of those disciplines into real life experiences and situations". According to Silva and Santos (2021, p. 7, our translation)

> From a school perspective, interdisciplinarity is not intended to create new disciplines or knowledge, but to use knowledge from various disciplines to solve a concrete problem or understand a given phenomenon from different points of view. In short, interdisciplinarity has an instrumental function. It is about resorting to directly useful and usable knowledge to respond to contemporary social issues and problems.

Bosch (2019) also emphasizes that interdisciplinarity seeks to bring disciplines together so as to form a single lens of vision, to see the problem in a broad way, and not from multiple and different disjointed lenses. The author explains that the idea is to find commonalities between the disciplines, in order to form a more comprehensive understanding of a complex issue.

The current trend, increasingly, is the perception of the whole, the complex view of the world (GERHARD; ROCHA FILHO, 2012). According to Raynaut (2015a), contemporary science is faced with complex issues, so the growing permeability of boundaries between institutionally established disciplines is inevitable. He claims that there are exchanges and collaborations between them, and that this aspect becomes an absolute necessity. Therefore, the school must provide students with an integrated education, which articulates the subjects in common themes, so that the student can understand the phenomena and problems in a more general and complete way. For Styron (2013, p. 47),

> Interdisciplinary education allows students to see different perspectives and work in groups with the synthesis of disciplines the ultimate goal. Encouraging students to reach beyond the typical constraints of a single content area and engage in interdisciplinary learning fosters critical thinking, creativity, collaboration, and communication skills.

The author emphasizes that interdisciplinary education allows students greater capacity in decision making, skills with regard to identification, analysis and problem solving. In addition, it highlights contributions to students' understanding of global issues, helping to develop new perspectives and values. The Common National Curriculum Base (BNCC) proposes

> [...] overcoming the radically disciplinary fragmentation of knowledge, encouraging its application in real life, the importance of context to give

> meaning to what is learned and the role of the student in their learning and in the construction of their life project (BRASIL, 2017, p. 15, our translation).

In addition, it also points out the need for

> [...] deciding on forms of interdisciplinary organization of curricular components and strengthen the pedagogical competence of school teams to adopt more dynamic, interactive and collaborative strategies in relation to the management of teaching and learning (BRASIL, 2017, p. 27, our translation).

In this sense, it can be seen that interdisciplinary projects, with the objective of articulating the disciplines in order to promote an integral vision of the phenomena of reality, are in line with what the BNCC advocates. Despite this, there are still few schools that carry out interdisciplinary projects in practice or that integrate the subjects in their curriculum proposals (GERHARD; ROCHA FILHO, 2012). It is known that this scenario is due to some factors that are highlighted by Fazenda (1991), such as: lack of time for joint meetings, lack of projects and collective work in schools, low interest in terms of integration between subjects and people, lack of common goals within the group, need for coordination and adequate remuneration.

Fazenda, Varella and Almeida (2013) highlight five principles that must exist in interdisciplinary teaching practice: "humility, consistency, waiting, respect and detachment" (p. 853, our translation). They also argue that teachers in the field of Education who wish to be more active need changes, such as new attitudes, procedures and concepts. That's why the aforementioned principles are essential for there to be partnership in the joint work of teachers. Styron (2013, p. 50) emphasizes that "[...] instructors participating in interdisciplinary education should have excellent communication skills and high levels of creativity. They should believe in team-teaching and active learning, have confidence in their abilities and not be afraid to take a risk."

Raynaut (2015b, p. 549, our translation), when describing a concrete experience about interdisciplinary practice, also reveals some questions that he considers important: "Dialogue; Respect for the diversity of points of view; Convergence search; Elaboration of a common problem; Careful articulation of methodologies". This finding by the author implies the establishment of a partnership between professors participating in the interdisciplinary practice, as they are the ones who must establish dialogues, reach agreements, respect opinions, articulate the concepts of each specialty and have a common objective. Neves (2015, p. 475, our translation) proposes "[...] looking at interdisciplinarity with an applied approach from which derives a pedagogy of encounter, dialogue, complementarity and mutual enrichment". Therefore, it is essential to work in groups, in partnership, to promote interdisciplinary activities.

Japiassu (1999, p. 96, our translation) emphasizes that

> Developing an interdisciplinary spirit causes attitudes of fear and refusal. Because it constitutes an innovation. And everything new is bothersome, because it questions what has already been acquired, what has already been instituted, what has already been fixed, what has already been accepted, in addition to questioning mental structures. What is at stake is a new

> conception of knowledge, a different way of conceiving its distribution and the process of its teaching.

The author explains that this new way of teaching generates uncertainties, fears, insecurities, especially for professionals who learned in a fragmented way and are used to teaching in a fragmented way as well. However, the trend towards an interdisciplinary path is undeniable, and it is therefore necessary to face difficulties. The author adds that

> It is important not to forget that educators need to be aware that, despite the extreme specialization that characterizes current science, students need to dream of a unity capable of transcending the ideology of disintegration and dispersion of knowledge. And that this knowledge can be reconciled by an interdisciplinary spirit, playing more or less the role of an orchestra conductor (JAPIASSU, 1999, p. 98/99, our translation).

Corroborating this idea, Bosch (2019) emphasizes that the broad aspiration of interdisciplinary education is to teach what will actually be important in students' lives, not only with regard to knowledge, skills and social attitudes, but in a broader perspective, such as problem solving and skills to apply what they learned even after completing their studies. In this way, he states that “Learning is consolidated through addressing real world problems in class” (BOSCH, 2019, p. 39).

In view of what has been exposed in this framework, the path that education needs to take to be in accordance with the current and globalized world in which we live, is that of interdisciplinarity. In this sense, it is increasingly necessary to invest in interdisciplinary teaching activities, strategies and practices from Basic Education to Higher Education.

DESIGN-BASED RESEARCH

To carry out this research, we chose to use Design-Based Research (DBR), which consists of a theoretical methodological assumption elucidated by Brown (1992) and Collins (1992). According to Brown (1992, p. 143)

> This is intervention research designed to inform practice. For this to be true, we must operate always under the constraint that an effective intervention should be able to migrate from our experimental classroom to average classrooms operated by and for students and teachers, supported by realistic technological and personal support.

The DBR, therefore, is carried out in real learning environments, promoting interventions that seek to inform what works, and what does not, in the practice of a classroom. Kneubil and Pietrocola (2017, p. 1, our translation) state that “Design-Based Research involves a new methodology that seeks to combine theoretical aspects of educational research with educational practice”. In this sense, research that promotes existing theories can be tested in educational practice and, based on the results obtained, theories can again be fostered with new aspects observed. It is a way of conducting investigations to test and refine educational projects based on theoretical principles, drawn from previous research (COLLINS; JOSEPH; BIELACZYC, 2004). Kneubil and Pietrocola (2017, p. 2, our translation) still comment that

> The most important feature of this type of research is to approach the constraints of schools and the practices of science teachers in order to understand the limits and possibilities of educational proposals that generate improvements in teaching and learning.

By developing the DBR in a specific context, it is possible to identify the limits and challenges to be faced on the spot, and thus seek truly effective solutions to solve real problems. Wang and Hannafin (2005) attribute some characteristics to DBR, namely: pragmatic, for seeking the refinement of theory in practice and attributing value to theory, as it informs and improves practice; situated, as it is performed in real learning contexts; interactive, as investigators work together in the process, that is, a working group is formed; iterative, as it has a cyclical character, with cycles of planning, implementation, analysis and redesign; flexible, as the initial plan can be modified when necessary; integrative, as several methods can be used; and finally, contextual, as it must be fully documented, so that it can be replicated in new contexts.

In the present study, the DBR phases elaborated by Reeves (2000) were adopted and that are also present in other works (HERRINGTON et al., 2007; PLOMP et al., 2009). For Reeves, the first phase of DBR is the identification and analysis of a real problem by researchers (researchers and professors involved in the research, for example). In a special way, the teachers who work at the school identify the problem. This is a key point of the DBR, which makes it different from other methodological assumptions. Generally, researchers want to research some aspect, and go to some school to research their wishes, test their hypotheses. In DBR, the investigation starts from a real problem that exists in the context in which the research is carried out.

The second phase of the DBR advocates the theoretical analysis of the problem and the search for solutions (REEVES, 2000). Those responsible for this search are the school's researchers and teachers. A group is established to analyze this problem based on existing theories and, thus, think of possible solutions to solve the identified problem. The solution refers to an artifact, which can be a scientific text, a technological tool, a guide for the teacher, a didactic resource (OLIVEIRA et al., 2009), teaching-learning strategies, programs, materials, systems, products (PLOMP et al., 2009), among others.

In the third phase of the DBR, the intervention with students takes place (REEVES, 2000). The artifact built earlier is applied in educational practice. It is also the time when data are collected, and different methodological resources can be used at this stage.

The fourth phase of the DBR consists of evaluating the process regarding the effectiveness of solving the initial problem and reflecting on design principles (REEVES, 2000). It also seeks, from the results obtained, to contribute to the theory. DBR allows you to redesign, that is, modify aspects of the process and artifact so that the next applications are more efficient. It is a cyclical process, which can be reformulated based on the results, so that it is increasingly valid and efficient.

In this article, the first and second phases of DBR are presented, since the objective here is to report the organization and elaboration of the interdisciplinary educational artifact. For Bittencourt (2013), it is important that the educational context and the needs of teachers working in the area are taken into account when identifying the problem and preparing the artifact, so that the latter assumes social relevance. She reports that this is made possible with a basic assumption of the DBR: partnership. For this reason, it is considered that the first and second phases deserve special attention, which is why this article was written.

METHODOLOGY

The work presented here is a descriptive research, considering its objective. According to Triviños (1987, p. 110, our translation) this type of research seeks to “exactly describe the facts and phenomena of a given reality”. The author emphasizes that the focus of these studies refers to getting to know the community, the problems, its characteristic features, its teachers, its education, preparation for work, among others. It seeks to know the characteristics and problems of the studied reality (ZANELLA, 2013). This research describes the planning of an interdisciplinary work, carried out from the theoretical and methodological assumptions of Design-Based Research. It presents, in detail, aspects related to the construction of an interdisciplinary didactic sequence (the artifact), as well as the potential, weaknesses and challenges of this planning. It seeks to contribute with authors, researchers and professors who wish to promote interdisciplinarity, and therefore, need to know the characteristics and problems faced in this lived experience.

The research was carried out in a school located in the interior of Rio Grande do Sul, and had as participants the teachers of the disciplines of Nature Sciences (Chemistry, Physics and Biology). To preserve the teacher's identity, a code was created to represent them. Professor F is responsible for the discipline of Physics and Chemistry. Professor B, on the other hand, is responsible for the discipline of Biology. For planning and debate on aspects related to the work, face-to-face and virtual meetings were held between the researchers (author of the work and advisor) and the teachers. It is noteworthy that the meetings did not always take place with the presence of everyone, due to the commitments of each one, however, the responsibility for communicating and informing all participants about the meetings was the responsibility of the researcher, author of the work.

Design-based Research was adopted as a theoretical-methodological assumption and, therefore, its phases and characteristics guided the entire research. This work describes the first and second phases of DBR outlined by Reeves (2000) and already described in the reference. It is not the objective here to describe the intervention, but rather the process of identifying and analyzing the problem, planning the solution and building the educational artifact. It is noteworthy that these steps are of paramount importance for the smooth running of the DBR and the success of the intervention. When dealing especially with the problem raised at the research site, related to the fragmentation of knowledge, the phase of planning and careful construction of the educational artifact to be implemented becomes even more relevant. There needs to be collaboration, attention and creativity when planning an interdisciplinary educational artifact. For this reason, we focused here on the description of this essential research step.

The research was submitted, evaluated and approved by the Research Ethics Committee (CEP) of the Franciscana University (CAAE: 18854819.0.0000.5306).

RESULTS AND DISCUSSION

The first phase of DBR consists in the identification and analysis of a real problem by researchers (REEVES, 2000). To define the problem in the school context, the researchers held a meeting with the teachers of Nature Sciences at the school. At this meeting, the DBR was explained, its phases and characteristics. More specifically, it was commented that the DBR foresees the formation of a design group, which in this case would be researchers and professors of the Natural Sciences. The role of this group was highlighted, which is responsible for: identifying the school problem, analyzing the problem from theoretical foundations, planning an artifact that seeks to solve the problem, applying it in a real classroom environment, and finally, analyze the entire process, checking the design principles and whether there is a need to redesign the artifact for new cycles. The teachers agreed to carry out the DBR together with the researchers. The first author of this work already knew the teachers at the school and, in a way, knew their anxieties and difficulties.

From this conversation, the problem was identified, especially by the teachers. They argued about the difficulties that students have in relating the contents of the disciplines of the Natural Sciences. Professor F, who is responsible for the disciplines of Physics and Chemistry, argued that in his classes he tries to make interrelationships between the contents, but gets few positive responses from students. Even with the professor's attempts, students have difficulties in articulating, relating, seeing science as a whole. In this sense, the study and planning of an interdisciplinary artifact was thought of, in order to try to articulate the concepts of these disciplines.

A search was carried out to verify theoretical aspects of interdisciplinarity and the fragmentation of knowledge described in the literature. In the framework of this article, some results found have already been exposed. It can be inferred, therefore, that the problem identified by teachers in the research context also occurs in other educational environments.

The design group reached a consensus: to work in an interdisciplinary way, it would be interesting to choose a theme that could include concepts from the three disciplines. There was also the need to choose a school year, so that the theme could be chosen. The teachers and researchers found the first year of high school adequate. Thus, there was a verification of the curriculum programmed for the first year of high school, with regard to the syllabus for Biology, Chemistry and Physics. Based on these contents, it was possible to think of a theme that would include them: Radiation and Radioactivity. Table 1 illustrates the programmatic contents that were highlighted by the design group, to be articulated involving the theme Radiations and Radioactivity.

Table 1 - Syllabus for the first year of high school identified by the design group as suitable to address the theme Radiation and Radioactivite

Biology	Nucleic acids and their composition; Gene and chromosomal mutations; Cell division.
Chemistry	Radioactivity (atom structure, radioactive elements, types of radiation, transmutation of radioactive atoms, decay, half-life time); Chemical bonds.
Physics	Nuclear energy.

Source: Own author (2020).

Initially, Radiation and Radioactivity were foreseen in the curriculum to be specifically addressed in the subject of Chemistry, however, the proposal of this research extends the study of this theme to other subjects of the Natural Sciences. From this, a research was carried out in the literature to find out how this theme is commonly dealt with in Basic Education.

Medeiros and Lobato (2010), in their research, emphasize that in Chemistry textbooks, nuclear radiation is especially addressed, while Physics textbooks predominantly bring electromagnetic waves. In some textbooks analyzed, the authors argue the lack of interconnection between the contents, hindering student learning, as highlighted below:

> Although nuclear and some electromagnetic radiation are described in the works (books Q1 and Q2), there is a lack of a connection between the contents, which possibly makes it difficult for students to create a relationship between these two types of radiation. And this lack of connection between the contents ends up leaving the false impression that the contents are not related. (MEDEIROS; LOBATO, 2010, p. 68, our translation).

Another research, carried out by Cordeiro and Peduzzi (2010), reveals that in national and international periodicals, the interest related to the teaching of Radioactivity only decreases. In addition, the authors state that the few works that exist are found mainly in the subject of Chemistry (CORDEIRO; PEDUZZI, 2010). It can be seen that, generally, the Radiation and Radioactivity theme is little worked on in Basic Education and, when worked, it is from the perspective of a discipline, in a fragmented way.

The BNCC was also analyzed to verify how the document provides for the teaching of Radiation and Radioactivity in High School:

> [...] global and local issues with which Science and Technology are involved – such as deforestation, climate change, nuclear energy and the use of transgenics in agriculture – have already begun to incorporate the concerns of many Brazilians (BRASIL, 2017, p. 547, our translation).

The paragraph refers to some concerns that the world faces regarding Science and Technology, such as Nuclear Energy. The importance of understanding the reasons for these concerns is highlighted, so that the student can finally have a critical view of the issues, give his opinion and seek solutions. Corroborating this idea, the document highlights the importance of an articulated look in the area of Natural Sciences, as described:

> It is important to highlight that learning Natural Sciences goes beyond learning its conceptual contents. In this perspective, the BNCC in the area of Natural Sciences and its Technologies - through an articulated view of Biology, Physics and Chemistry - defines competences and abilities that allow the expansion and systematization of essential learning developed in Elementary School in which refers to: the conceptual knowledge of the area; the social, cultural, environmental and historical contextualization of this knowledge; to the processes and practices of investigation and to the languages of the Sciences of Nature (BRASIL, 2017, p. 547, our translation).

In this excerpt, the intention to promote "an articulated look at Biology, Physics and Chemistry" is clear. Therefore, BNCC bets on strategies that go beyond the assimilation of fragmented concepts and recommends that students be able to articulate them to obtain a better understanding and learning about the contents, concepts and phenomena. It also uses the word "contextualization", reinforcing the purpose of connecting this knowledge to everyday life.

A specific skill of the document, which is related to the teaching of Radiation and Radioactivity, corresponds to

> ((EM13CNT103) Use knowledge about radiation and its origins to assess the potential and risks of its application in equipment for daily use, in health, in the environment, in industry, agriculture and in the generation of electricity (BRASIL, 2017, p. 555, our translation).

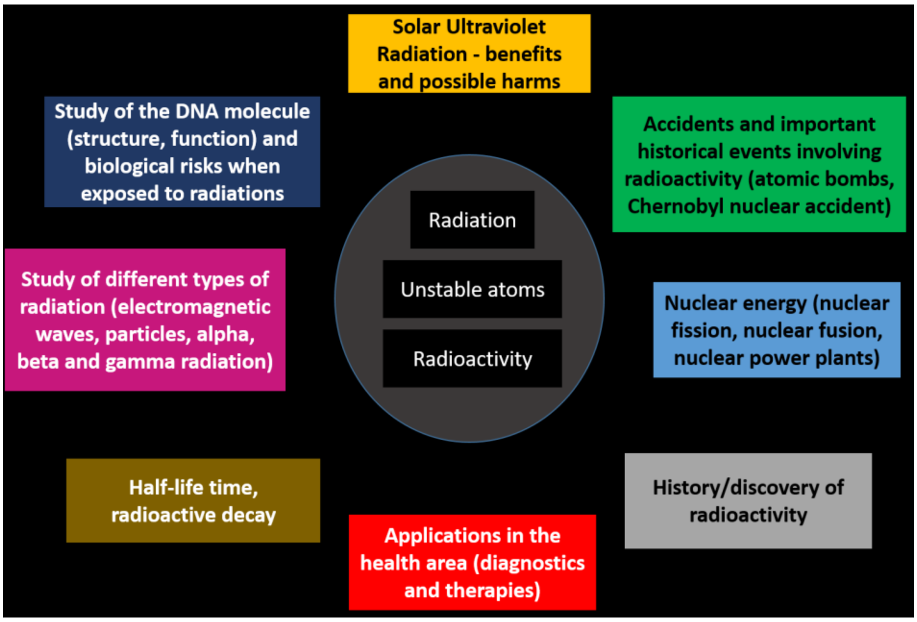
It is noticed that the BNCC proposes an overview of Radiation and Radioactivity, so that the student can understand its applications in everyday life. This interpretation of the world becomes easier and possible when the concepts learned at school are articulated, forming a knowledge network capable of stimulating students' thinking. Thus, students become more critical, able to reflect on the various aspects and possibilities that involve a theme.

It can be seen that the trend established by the BNCC, for example, is an interdisciplinary approach, an overview that allows students to understand this subject in a broad way. In this context, the design group met to elaborate an educational artifact that could contribute to interdisciplinary teaching and articulate the Radiation and Radioactivity theme.

Therefore, the second phase of the DBR was started, which consists of the theoretical analysis of the problem and the search for solutions (REEVES, 2000). A mental map was built by the design group, with the articulations of the concepts foreseen for the first year of high school, in the area of Natural Sciences, in relation to the Radiation and Radioactivity theme. Augusto et al. (2004, p. 280, our translation) emphasize that "The image of a network or web of meanings is a good representation of interdisciplinary work, with its links and nodes". This mind map served as a guide for the design group. It's a very clear visual form that exposes the possible connections that can be made.

Due to the size of the mind map, it is understood that it can be difficult for the reader to visualize its content. Therefore, Figure 1 was elaborated, which briefly presents the general topics covered in each color block, in order to facilitate the reader's understanding of the constructed mental map.

Figure 1 - General topics present in the mind map



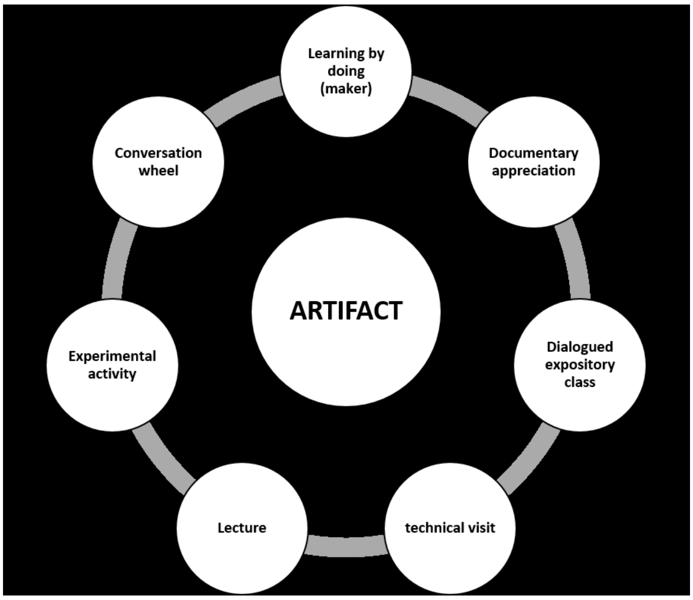
Source: Own author (2020).

After the construction of the mental map, it was easier for the design group to visualize the articulations of the concepts. The colors of the map were purposely chosen according to the specific subjects that involve the theme. It is noteworthy that these subjects cover concepts from the three disciplines. Therefore, in each color block, there is a subject on the subject that involves concepts of Biology, Chemistry and Physics. The design group then decided to plan a didactic sequence, which consists of the DBR educational artifact. We opted for the elaboration of a didactic sequence due to the possibility that it brings to approach different strategies before the same focus. According to Peretti and Costa (2013, p. 6, our translation) the didactic sequence is

> [...] it is a set of activities linked together, planned to teach content, step by step, organized according to the objectives that the teacher wants to achieve for their students' learning and involving assessment activities that can take days, weeks or throughout the year. It is a way of fitting the contents to a theme and, in turn, to another, making knowledge logical to the pedagogical work developed.

The didactic sequence consisted of eight strategies that cover concepts related to the theme in a different way. Therefore, the strategies address different and diversified methods, as can be seen in figure 2. It is noteworthy that there were two expository-dialoged classes, therefore, figure 2 presents seven different methods that contemplated the sequence.

Figure 2 - Methodological strategies that make up the DBR educational artifact



Source: Own author (2020).

As a result, it was decided to adopt different strategies, considering that not all students learn the same way, that is, each person learns in their own way (PEREIRA, 2010). Thus, by diversifying the strategies, everyone can be reached, promoting classes that are different from each other. Each strategy sought to address a subject (color block) of the mind map.

In total, eight strategies were planned, which have the specific objectives and the content they address, shown in table 2.

Table 2 - Strategies of the artifact, with their respective objectives and covered content

STRATEGY		GOALS	CONTENTS
1	LEARNING BY DOING (MAKER) - Construction of the DNA molecule	Understanding the structure of the DNA molecule, its components and functions.	* Nucleic Acids and their composition (nitrogen bases, pentose, phosphate group); * Chemical Bonds (hydrogen bond and covalent bond); * Biological function of DNA (genetic information).
2	DOCUMENTARY ASSESSMENT - Documentary: “The Nobel Prize Saga – The Curie Clan”	Knowing when, how and by whom Radioactivity was discovered, and what were its influences on society.	* Radioactivity (atomic instability); Radiations; Origin of Radioactivity; Origin of X-ray;

	STRATEGY	GOALS	CONTENTS
3	DIALOGED EXHIBITION CLASS - TYPES OF RADIATIONS	Characterizing which radiations exist, highlighting their characteristics, properties and applications.	*Alpha Radiation, Beta Radiation, Gamma Radiation, Electromagnetic Radiation (Electromagnetic Waves); *Penetrability of Radiation; * Structure of the Atom.
4	TECHNICAL VISIT - Instituto de Radiodiagnostic	Learning about the applications of Radiation and Radioactivity in the health area, more specifically, in medicine.	Diagnostic exams (Radiography, X-Ray, Mammography); Radiations used; Disease treatments.
5	LECTURE -“Solar Ultraviolet Radiation: good guy or villain?”	Understanding the harms and benefits of Ultraviolet Solar Radiation for living beings.	DNA Injuries and Mutations; Vital energy (photosynthesis, carbon and oxygen cycle, bone health); Electromagnetic radiation; Protection Methods (sunscreen).
6	DIALOGED EXPOSITIVE CLASS - Nuclear Energy	Elucidating the advantages and disadvantages of Nuclear Energy.	Nuclear energy (nuclear fission, nuclear fusion, atom structure, chain reaction, radioactive waste, radioactive fuels, atomic bomb, risk of accidents).
7	EXPERIMENTAL ACTIVITY - Simulation of radioactive decay	Understanding how radioactive decay occurs.	Radioactive decay (half-life time, equation and exponential graph).
8	TALKING WHEEL - Reflection on the atomic bomb in Hiroshima and the nuclear accident in Chernobyl	Understanding and socializing opinions about the events in Hiroshima (1945) and Chernobyl (1986).	Atomic bombs; Nuclear power plants; Ecology (fauna and flora, aquatic environments, radioactive waste); Biological effects (atomic bomb survivors and Chernobyl residents).

Source: Own author (2020).

It is emphasized that, in addition to working the theme in an integrated and interdisciplinary way, the didactic sequence was designed to provide students with different ways of learning, since there are individual particularities of each person with regard to ways of learning. We also sought to explore the interrelationships between the three disciplines on the subject of Radiation and Radioactivity. According to Lapa, Bejarano and Penido (2011, p. 3, our translation)

> [...] in the idea of interdisciplinarity, disciplinary actions on a given topic are articulated through a set of coordinated activities that aim to build a common object. This demands an integrating element that establishes a hierarchical level capable of coordinating interdisciplinary actions.

For the elaboration of the sequence, several conversations between the professors and the researchers were necessary, definitions of the concepts that would be addressed in each strategy, as well as the key aspects that served as integrators or articulators. Therefore, some weaknesses found in the process are highlighted. Teachers participating in the research worked in more than one school, that is, they had more than one workplace. So his days were always very busy, and there was little time for meetings to take place. Thus, the alternative found was the use of digital technologies, especially cell phones and the Whatsapp application, so that joint conversations could take place between all members of the design group. Even so, there were several face-to-face conversations. In all of them, the researcher (author) was present and passed on the combined information to the rest of the group, in case anyone could not attend. There were, therefore, difficulties at this point, but the solution found allowed communication to take place.

Another weakness that also influences planning is the little time that schools allocate for meetings between teachers. Generally speaking, there are no times when teachers can meet to plan together, or think about integrative, interdisciplinary practices. What is predominant is compliance with the curriculum established at the beginning of the academic year, for each subject. In this aspect, the professors got very involved and managed to adapt the interdisciplinary planning developed together, making everything happen. This fact reinforces what has already been said in the literature review, the willingness and commitment of teachers is crucial to the effectiveness of interdisciplinary work, however, one should be aware that a truly interdisciplinary work requires more than commitment and goodwill. It requires a rethinking of the curriculum as a whole, in the sense that the school itself needs to take an interdisciplinary posture in its teaching proposal.

FINAL CONSIDERATIONS

This article is part of a master's thesis, in which the general objective was to articulate the knowledge of the Natural Sciences, through a Design-based Research. Here, the proposal was to present how the identification of the research problem occurred in the context of the school, the process of analyzing this problem and the search for solutions, in addition to the description of the elaboration of an interdisciplinary didactic sequence (educational artifact) on the theme Radiations and Radioactivity. These steps, as described in the reference, refer to the first and second phases of the DBR, established by Reeves (2000). The didactic sequence elaborated had several methods and different strategies, in order to promote a wide study of the Radiation and Radioactivity theme.

Here, the interactive feature of the DBR is highlighted. Based on the researcher’s observations, it is considered that this characteristic - of working together, with groups and partnerships - contributes to the use of DBR in interdisciplinary projects, since both in the readings about interdisciplinarity and in the readings about DBR, there is the idea of the need to work together. Bittencourt (2013) emphasizes that one of the basic assumptions of DBR is partnership, working in collaboration. Likewise, Styron (2013) affirms the importance of teamwork in interdisciplinarity. This point reinforces the potential of using PBD to develop interdisciplinary projects. In addition, another interesting point is the organization of Design-based Research into phases, established by Reeves (2000). This organization confers a certain methodological rigor to be followed which, in the researchers' conception, facilitated the process of organizing and elaborating the artifact.

Thus, it is considered that the contribution of this article concerns the possibility of other professionals who work in research in teaching, or even in teaching, to carry out similar interdisciplinary projects, using the same steps used here. The expectation is that, increasingly, there will be new works and interdisciplinary projects in teaching, corresponding to current trends in the world and globalization.

Planejamento de um artefato educativo interdisciplinar: potencialidades, fragilidades e desafios

RESUMO

Atualmente, existem preocupações com relação ao ensino fragmentado da Ciência. Assim, assume-se como tendência um ensino interdisciplinar, capaz de apresentar aos estudantes a visão do todo, mais próximo à realidade. Nesse sentido, este artigo busca descrever o planejamento de um artefato interdisciplinar elaborado para promover a articulação dos saberes das Ciências da Natureza. Trata-se de um recorte de uma pesquisa de mestrado, concluída no ano passado. É uma pesquisa descritiva, guiada pelos pressupostos teórico-metodológicos da Pesquisa baseada em Design. Aqui, apresenta-se, especificamente, a descrição do processo no que tange às seguintes etapas: formação do grupo de design; identificação e análise do problema no contexto escolar; análise e busca por soluções; construção e organização do artefato educativo. Como resultados, apresenta-se a organização e o planejamento de um trabalho interdisciplinar sobre a temática Radiações e Radioatividade, ressaltando potencialidades, fragilidades e desafios do processo. Acredita-se que este trabalho pode auxiliar pesquisadores e professores que almejam realizar projetos interdisciplinares e promover a articulação dos saberes em suas práticas. Além disso, por mais que este trabalho verse sobre as disciplinas das Ciências da Natureza, a forma como foi realizado pode ser replicada para articulação de conceitos referentes a outras áreas do conhecimento, ou até mesmo, para a articulação entre diferentes áreas do conhecimento.

PALAVRAS-CHAVE: Ciências da Natureza. Pesquisa Baseada em Design. Interdisciplinaridade. Articulação dos saberes. Ensino.

NOTES

1. O presente texto, originalmente escrito na língua portuguesa, foi traduzido pelo tradutor profissional da língua inglesa, André de Campos Lopes, e-mail: andrewizard77@gmail.com, telefone: (55) 99194-8986.

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