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What Are and How to Teach Big Ideas of Science Education: Stories from the Discussion around a Teacher´s Practice

Qué son y cómo enseñar las "Grandes Ideas de la Ciencia": relatos desde la discusión en torno a una práctica de aula

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Abstract

The big ideas of science education are the current changes in the science curriculum all over the world and also in Chile. Experiences of lessons using big ideas are, mostly, from the Academia describing what and how teachers teach in their classrooms, generating a lack of the teacher´s practice since their own voice. This research explores, under the collaborative self-study methodology (Bullock & Russell, 2012), the practice of an undergraduate level´s teachers where it is developing the reflexion and self-knowledge about the Big Idea of living being. The results show that it is possible to build with the students a Big idea from "small" ideas since the analysis of concrete examples. Furthermore, for this teacher, the big idea as a guideline that promotes more flexibility and confidence in the students´ knowledge. Finally, considering critical friendship and the sharing of the experience benefit reflexion of the practice and learning of everyone.

Keywords: Big Ideas in Science, collaborative self-study, preservice teacher education, living being

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Abstract

Las Grandes Ideas de la Ciencia son parte de los actuales cambios a los currículos de ciencia a nivel internacional y en Chile. Experiencias sobre clases usando Grandes Ideas de la ciencia provienen principalmente desde la Academia, describiendo qué y cómo realizan clases otros profesores en sus aulas, dejando una brecha respecto de lo que ocurre en la práctica de los profesores desde su propia voz. Este trabajo explora, bajo la metodología de *self-study* colaborativo (Bullock & Russell, 2012), la práctica de una profesora de formación inicial con sus estudiantes de pedagogía en biología, a partir de la cual se gatilla la reflexión y el autoconocimiento, en torno a la exploración de la Gran Idea de *ser vivo.* Los resultados muestran que es posible construir con los estudiantes una Gran Idea a partir de ideas más pequeñas que emergen del análisis de ejemplos concretos. Para la docente, el orientarse por una Gran Idea facilita la enseñanza por cuanto permite mayor flexibilidad y confianza en el conocimiento de los estudiantes. Finalmente, el contar con un amigo crítico y compartir la experiencia contribuye a la reflexión sobre la práctica, generando un camino de aprendizaje conjunto que beneficia a todos.

Palabras clave: Grandes Ideas de la Ciencia, self-study colaborativo, formación inicial, ser vivo

"For many years, my dream has been to work on the concept of a living organism from an integrated perspective. I have always been fascinated by imagining what living organisms are and how they work, but at the same time I have always felt discouraged by the atomistic approach that is used to teach it: traditionally, the concept of a living organism is taught piecemeal…" (HC-P)[1]

What are big ideas?

In many countries, the changes being implemented in the science curriculum concern the "big ideas of science". The term gained traction as a result of the work of a group of science education researchers, teachers, and engineers from several countries led by Wynne Harlen. This group presented its ideas in two short books: *Principles and Big Ideas of Science Education* (2010) and *Working with Big Ideas of Science Education* (2015b). These publications were aimed at proposing key ideas for inclusion in the curriculum, in order to help students understand, enjoy, and marvel at the natural world and thus contribute to tackling the issue of their negative attitudes toward science (Harlen, 2010, 2015a, 2015b).

Multiple definitions of these "big ideas" exist and many suggestions have been made regarding how to teach them. According to Mitchell, Keast, Panizzon, and Mitchell (2016), big ideas are "a unifying principle that connects and organizes a set of smaller ideas or concepts with multiple experiences" (p.3), noting that these ideas are large in scope since they orient teaching. Mitchell et al. (2016) cover several definitions of big ideas, such as that advanced by Hume and Belly (2011), for whom "key ideas are autonomous statements that convey a feeling of lasting understanding that students must build on" (quoted in Mitchell et al., 2016, p. 3). For Whiteley (2012), big ideas "can be thought of as the meaningful patterns that make it possible to connect knowledge dots that would otherwise be fragmented" (quoted in Mitchell et al., 2016, p.3). For other authors, a big idea is not only a part of disciplinary knowledge: it must also promote links within its scientific discipline and be generative for students, thus enabling them to create new connections within the contents covered (Olson, 2008; Smith III & Girod, 2003). In addition, they are common to multiple phenomena and can be potentially developed over time (Plummer & Krajcik, 2010). In the US, big ideas have been defined by Project 2061 of the American Association for the Advancement of Science (AAAS) as "relevant topics for scientific, mathematics, and technology literacy" (Lelliott & Rollnick, 2010, p. 1173); more recently, the Next Generation Science Standards (NGSS), published in 2013, addressed the issue of the coverage and depth of basic, curriculum-wide ideas connected with the big ideas of science (Metz, 2012).

1 Teacher's lesson story.

One of the advantages of teaching with big ideas is that students may be able to establish links between scientific concepts (Metz, 2012). Also, when these ideas are interconnected, it should be easier to use them in new situations (Harlen, 2015a). Likewise, if students are able to visualize how scientific ideas relate to each other, they could be inspired to develop a new understanding of science (Harlen, 2015a). Students may also be able to construct connections and recognize patterns in various phenomena (Harlen, 2015a) and attain a more sophisticated level of understanding (Plummer & Krajcik, 2010). For teachers, organizing topics around big ideas should make it possible to reach a deep understanding of scientific contents and establish links between the activities conducted (Mitchell et al., 2016). Finally, big ideas can encourage teachers to cover interdisciplinary scientific contents in an integrated manner (Cartier & Pellathy, 2009).

Using big ideas: some examples

The literature provides multiple examples of studies on big scientific ideas, such as big ideas about disciplinary content, learning, and proficiency (Mitchell et al., 2016); [big ideas about] homeostasis, evolution, information, interactions, and emergent properties (Cooper, 2015); [big ideas about] the Earth-Sun-Moon system (Lelliott & Rollnick, 2010; Plummer & Krajcik, 2010); [big ideas about] science (Devick-Fry & LeSage, 2010; Harlen, 2010, 2015b); and [big ideas about] the nature of science (NOS) (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003), among other topics. Each of these studies seeks to contribute to science teaching by identifying ideas that are essential for understanding certain concepts.

Several experiences have been documented with respect to the use of big ideas in teaching, designed by science education researchers and implemented by teachers in the classroom. In this regard, for instance, it is possible to observe how in-service teachers use a specific example, such as the life cycle of butterflies, as an interdisciplinary topic aimed at making it easier to understand life cycles in general (Cartier & Pellathy, 2009). Another example illustrates how, based on students' ideas about the apparent movement of celestial bodies, an intervention was designed with a number of learning trajectories and their outcomes (Plummer & Krajcik, 2010).

Although most of the experiences reported have an academic origin and were only implemented by schoolteachers, some practice-based examples exist in the literature: for instance, a primary school teacher who narrates how she uses big ideas in her lessons (Alleman, Knighton, & Brophy, 2010). In their work, authors define big ideas as powerful ideas liked to students' basic sets of knowledge, which tend to be disconnected and limited. Alleman et al. (2010) note that although it is hard to pay attention to lesson planning, implementation, and evaluation when using big ideas, lessons become more meaningful when these aims are met.

In brief, working with big ideas appears to involve organizing lessons around certain fundamental ideas that lay the groundwork for understanding other phenomena, while also making sure that students understand these key ideas and have opportunities to apply them in a variety of contexts.

The big idea of living organisms: understanding parts vs the whole

Harlen (2010) proposes several big ideas related to people's understanding of the concept of living organisms. Within the framework of this study, we wish to highlight two of them: "Living organisms are made up of cells" (BI 7) and "Living organisms need energy and materials that they often depend on and which they strive to obtain by interacting with other organisms in an ecosystem" (BI 8). In order to merge these ideas, we could state that living organisms' need to obtain matter and energy to stay alive determines a specific organization based on the cell, and that the functions of living organisms reflect cellular functioning.

One of the main problems with teaching the concepts of the living organism and the cell is the lack of connections established between the characteristics and functions of living organisms and cellular functioning (González-Weil & Harms, 2012). Likewise, the associations between various systems are not well understood either. A study with 268 first-year university students in Argentina showed that, in response to the statement "the operation of brain cells depends on the food absorbed by intestinal cells", very few participants were able to establish a functional connection between the brain and the digestive system (De Micheli, Iglesia, & Donato, 2003). Similarly, the relationship between digestion and cellular respiration with respect to energy intake is unclear. Many students (even at the university level) say that the processes for obtaining energy that can be directly used in metabolism are digestion in animals and photosynthesis in plants (Mweene, Sanders, & Mumba, 2012; Tekkaya, 2002), overlooking the role of cellular respiration. In general, the concepts of the living organism, the cell, its structures, and its function have been taught piecemeal and not from a systemic perspective, which makes it difficult to gain an overall understanding of these notions.

This study is aimed at exploring, from the perspective of collaborative self-study, the practices of a teacher educator and her group of preservice Biology teachers as she teaches the big idea of the living organism in an integrated manner. In this context, we ask: In what concrete ways is it possible to cover the big idea of the living organism in the classroom? How does working with big ideas contribute to the initial education of Science teachers? And, in the specific case of the authors, What can we learn about the implications and conditions that facilitate working with big ideas? What aspects are essential for learning to teach with big ideas?

Methodology

Approach and design

Epistemologically, this study is socio-constructivist: in it, knowledge is regarded as a process whereby those who conduct research actively engage in the construction and reconstruction of theory and practice (Carr & Kemmis, 2004). In this case, the object of study is the work of a teacher educator who uses big ideas to teach her group of preservice Biology teachers. The design used is based on collaborative self-study, as the teacher educator and a colleague (the authors) discuss and construct what the big ideas of science bring to teaching and their potential as a learning tool both in preservice teachers' education and as a teaching resource for their future classroom work. Self-study has been defined as a way of gaining a deeper understanding of professional knowledge, which is based on social constructions (Bullock & Russell, 2012).

Context and participants

This study was conducted within the context of a Biology Teaching course for third-year preservice Biology teachers. Twelve students (9 women and 3 men) took part in the course. This article describes a sequence of 3 sessions lasting 4 class periods each, conducted at the beginning of the first semester of 2017. The authors (who are also the participants) are a biology teacher with a graduate degree in biology teaching and a biologist with a graduate degree in science teaching. Both are experienced educators who have worked with preservice and in-service teachers.

Data production and analysis

Data were collected from the following sources: (a) Big Ideas Questionnaire (Cuestionario Grandes ideas, CGI), (b) teacher educator's (Corina) and students' lesson stories (HC-P/HC-E), (c) student productions (invented animal fact sheets, reflections), (d) whiteboard pictures (FP), (e) exit tickets administered to students at the end of the lesson (TS), (f) teacher's log (Corina) (Bit), (g) video recording of the PRETeC[2] group session in which one of the lessons was analyzed (SP).

Information was examined by conducting a thematic analysis on the whole dataset. According to Braun and Clarke (2006), thematic analysis is a method that can be used with research questions linked to people's practices, views, and opinions. In this study, this enabled us to understand how we conceptualized big ideas and how to teach them.

2 See Acuña, T., Avilés, D., Bravo, P., Cisternas, D., González-Weil, C., Henríquez, C., Maldonado, L., Palacios, L., Salinas, E., & Santana, J. (2016). Profesores reflexionando por una educación transformadora en ciencias (PRETeC) [Teachers Reflecting towards a Transformative Approach to Science Education]. *Docencia*, 60: 43-53.

To make the article easier to follow, results are presented in the first person, organized around "vignettes" illustrating the multiple stages of the research process.

Results

Vignette 0: Why work with a big idea?

Corina and I had been talking about the big ideas of science for a while. I (Paulina) am starting my PhD in Education and I have chosen to study in-service teachers' professional development in connection with the collaborative creation of the big ideas of science. In that context, I invited Corina to participate in a questionnaire administered to a group of teachers from the Valparaíso region, aimed at identifying how they conceptualized this term. Corina, in parallel to the lessons, noted how important it is for her to teach using big ideas, specifically with respect to living organisms:

> [Do you have experience teaching with big ideas? What idea?] "The idea that living organisms are autopoietic beings that need matter and energy to stay alive and not dissolve. [What class did you teach that to?] I've been using this idea with third-year preservice Biology teachers. [Why did you decide that was a big idea?] I think it's a big idea because it explains the existence and functioning of living organisms. One of the biggest problems of biology is that everything is taught in isolation. This big idea ties everything together and helps explain the basic functions of living organisms" (CGI).

I (Corina) have worked for nearly 20 years educating both preservice and in-service Biology teachers. All these years, I've felt let down by the disconnected way in which biological concepts are covered, not only in schools, in the school curriculum and textbooks, but also at the university level:

> Traditionally, the notion of a living organism is taught piecemeal. A living organism (usually a human being) has a digestive system, a circulatory system, a nervous system, and a respiratory system, and is also made up of cells, but we generally learn all that in separate boxes, and when someone asks what happens to the O2 we breathe or what happens to brain cells when the intestine fails, we realize we have no idea how these things are linked to each other (HC-P).

In this context, I was given the opportunity to teach a new course. Inspired by her PhD studies, Paulina had already introduced me to teaching with big ideas and challenged me to adopt that perspective in this course. I set out to work on the notion of a living organism in an integrated manner, so that my students would be able to visualize the fundamental ideas related to the functioning of living organisms and link their basic operations to cell-level events.

Vignette 1: Joint construction of the big idea: living organisms as autopoietic beings that require matter and energy to stay alive

In the first lesson, I (Corina) started by asking how we could define a living organism. My students listed several characteristics: "it has a life cycle, a metabolism, interacts with its environment, has a genome, reproduces, is made of cells". I asked them to think of something exclusive to living organisms, and they mentioned "autonomy". Based on this, we addressed the notion of *autopoiesis* and reached —through an analogy— the idea that, for a living organism to remain that way (alive!), it must obtain energy and matter:

> …if we build a house and do nothing to maintain it in 20 years, it will deteriorate. The only way to preserve it is to add **matter** (paint, new wood) and **energy** (painting, nailing boards). The same is true of living organisms (…) the natural tendency is to dissolve (which is what happens when we die) (Bit).

I (Paulina) think that the use of analogies and their connection to elements students encounter in everyday life has a lot of potential. When Corina told me what she was going to do in her lesson and when I read her story, I set out to do something similar. As part of my PhD, I had to show a (hypothetical) example of the use of big ideas in science lessons. I produced a lesson based on systems theory and organization levels. In my example, I asked students to make a paper plane and make it fly, first individually, and then in groups of 3, 6, 10, and 15. The aim of the task was to compare how students added features to the plane to make it fly better, combining elements from previous versions of the planes that they had made. At the end of the task, the features that they added could be regarded as the properties that we observe in each of the organization levels of matter, with emergent properties appearing in each successive level.

Vignette 2: A big idea is constructed based on several little big ideas: finding out how living organisms obtain matter and energy

The next step in my lesson (Corina) was to determine, as a group, how living organisms obtain matter and energy. To do so, I asked the students to form small groups and think of an animal they found interesting. Then, they searched for information on the Internet (using their cell phones) about how that animal obtained matter. They collected information about 7 animals: jellyfish, whale, dumbo octopus, axolotl, platypus, nematode, and starfish. Making comparisons in small groups first, and then with the whole class, we tried to find common elements regarding how these animals obtained matter. This led us to develop a few little big ideas (LBI) that we kept refining together (LBIs in bold): "The students pointed out several things: that there was an entry and an exit point for matter (which could be the same orifice, as in the jellyfish), and that in all cases matter was digested and absorbed" (HC-P).

As we tried to define what we were observing, a student proposed that all animals needed a "**system for transforming large matter into small [and assimilable] matter**" (LBI 1). This more or less solved the problem of matter intake. When I asked where that "small" matter went, the unanimous answer was: "to the cell". Then, a second need emerged: "**a system for distributing matter to all cells**" (LBI 2).

I then asked where animals obtain their energy from. The answer was less clear:

> This question proved to be a bit harder. Some students thought that "obtaining matter" (eating) automatically entailed energy intake (when in fact what happens at first is that the matter is "made smaller"). After a while, a student mentioned cellular respiration, which we defined as "**a process whereby energy is extracted from matter (generally glucose), which requires O_2 (in most cases), and yields ATP, CO_2, and H_2O (while also transforming organic matter into inorganic matter)**" (LBI 3) (HC-P).

This caused another little big idea to emerge: living organisms need "**a gas exchange system (O_2 intake and CO_2 discharge)**" (LBI 4). Each group checked the characteristics of said system in "their animal". After sharing the findings of our comparison of various respiratory systems, we identified a common trait: "**the existence of a wet surface where gas exchange takes place**" (LBI 5).

Although we managed to construct 5 little big ideas, our discussion was not free from doubts (some of which I also shared); for instance, what happens with tapeworms, which are endoparasites? (since everything is apparently digested, do they have a digestive system? do they breathe? how?).

Due to this, Corina and I (Paulina) talked about the "blocks" that make up big ideas. We became interested in their size and their limits, and thought about how to define them with our students. Both the use of analogies and the ability to identify common elements by comparing concrete examples (comparative anatomy or paper plane making) appear to be useful strategies for constructing the bricks that make up a big idea. Our discussion also led us to think about the links between big ideas and about the learning progression that can be achieved.

Vignette 3: Applying the big idea (and little big ideas too!): "It's hard to play God!"

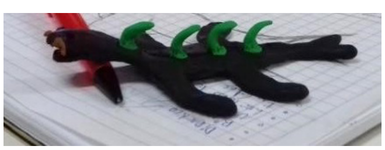
In the previous lesson, we had jointly constructed what I (Corina) considered were basic characteristics of living organisms. This led me to propose, somewhat reluctantly, the following challenge:

“I listed several habitats on the board: water (salt/fresh; superficial/deep); earth (superficial/underground), host (inside another living organism). The challenge was to invent the weirdest animal possible that met all the conditions for staying alive we had identified. I gave the students some modeling clay [so they could create this being] and told them that they had to fill in a card that included its common and scientific name, its behavior, and some unusual facts, along with an explanation of how they obtained matter and energy. We took a break. When the students returned to the classroom (and after everyone had finished), I wrote on the board: **First Conference on Invented Animals**. Each group gave a presentation about their animal” (HC-P).

So, we got to know a number of specimens: the vecat (*Felis acuasilvestris concolor*), a vegan feline that spends half the year on the land and the other half in the sea; the plungy (*Sopapitus ostium*), a sort of sea worm that eats using its arms, which are shaped like toilet plungers; the near-hummingbird (*Rapidicense chernobilicus*), which resembled a common hummingbird that had grown 4 legs and 2 wings due to radiation from the Chernobyl accident; gary (*Espherium luxaltitudo*), a very strange being that inhabits one of the 7 Earth-like planets discovered by NASA, and the Easter catfish (*Ikalarus chilensis*), AKA Pablo, a blind Chilean fish that lives 5,000 meters under the seas around Easter Island. The following are some extracts from the fact sheets of the invented animals:

*“**Habitat:** Extraterrestrial, marine.*
***Diet:** Photosynthesis and small marine invertebrates.*
***Behavior and curious facts:** In case of danger, it adopts a spherical shape. This happens due to its segmented body, which enables it to become ball-like. It has luminous antennae that allow it to live deep under the sea. When food is scarce, it can swim to the surface and use the dim sunlight to perform photosynthesis…”* (Gary fact sheet).

“…it is totally blind due to its environment, where sunlight does not reach, but it has whiskers on its face which it uses as echolocators to detect nearby creatures or structures (…) It feeds on animals dragged by the currents or those slower than itself, because it moves slowly” (Easter catfish fact sheet). Figure 2
Easter catfish



As the groups presented their animals, the rest asked questions such as “what’s its lifespan?” or “how does it get oxygen for breathing so deep underwater?”, “how does it regulate its temperature when it enters the water?”. In some cases, the questions made us laugh (“What’s its lifespan? — We don’t know... the first one hasn’t died yet”), but sometimes they challenged the animal’s “survival” or adaptation to its supposed habitat, which forced the groups to make some “adjustments” to their creations. When asked about the hardest part of the task, most students mentioned that it was the need to invent something “that doesn’t exist” based on existing things, thinking in an organized and consistent manner about all the characteristics that an animal would need to “survive” in its habitat:

> [The hardest part for me] was to connect key biological concepts to generate an organism that would be able to live"; "the hardest thing for us was to think of all the characteristics and needs of the animal according to its environment while making it as efficient as possible"; "to design an animal that would be able to survive and make its systems consistent with one another" (It's hard to play God) (TS).

Looking back, I realize that two interesting phenomena occurred during this activity. First, the students had fun and were very creative. Despite the entertainment focus of the activity, they worked hard to meet the requirements necessary to keep their creations "alive". Second, the activity truly challenged them and forced them to think about how the various systems of a living organism were connected to each other.

> We moved forward, certain that we had identified (at least considering what we had studied thus far) all the characteristics we needed for Pablo to be able to survive. When we shared our creature with the whole class, we realized that many characteristics that we had chosen ended up undermining it. After a few corrections, we managed to find some features that at least enabled it to stay alive (HC-E).

I (Paulina) remember that when Corina told me about this activity, I asked her about the notion of "necessity", and talked about how it can lead to conceptual errors, for instance regarding evolution. If we think of which characteristics living beings "must" develop to survive in a certain environment, we are to some extent alluding to the view that organisms (individually) develop certain traits "at will", which could lead to preconceptions when trying to understand evolutionary processes. Usually, when we teach lessons on biological systems, we use words such as "need" or "this organ performs this function" from a perspective of finality; therefore, we tried to be aware of our language when teaching in order to avoid generating alternative conceptions.

Vignette 4: Expanding the big idea: photosynthesis as a starting point

During this third stage, I (Corina) reminded students of the big ideas that we had devised and asked them whether they also applied to plants. We had a chart that read: "Matter: System for transforming large matter into small/assimilable matter (LBI 1); Matter distribution system (LBI 2); Process for extracting energy from matter (LBI 3); Gas exchange system" (LBI 4) (FP). When students noted that the first idea did not apply to plants because they "made their own food", I challenged them to understand how photosynthesis works. They arrived at the following idea: "**Photosynthesis: A process that transforms luminous energy into chemical energy and inorganic matter into organic matter**" (LBI 6).

When asked whether LBIs 2, 3, and 4 applied to plants, some students initially confused cellular respiration and photosynthesis and initially doubted whether plants needed oxygen (but quickly clarified this among themselves), after which they concluded that LBIs 2, 3, and 4 did apply to plants. However, the students wondered what happened with trees in autumn. In response to this issue, a student explained the seasonal differences in tree growth and the formation of rings in tree trunks.

After this session, we spent many others covering the carbon cycle (using a short story). The students completed their invented animal with other systems that would make it more viable (e.g. nervous, excretory, locomotion system). Lastly, we simulated an ecosystem where the students' creations interacted with other new beings (mainly plants). The students were asked to explain how matter and energy flowed in it.

Vignette 5: Sharing our work with big ideas: learning from colleagues and students

Some weeks after the lessons described, I (Corina) plucked up the courage to write a lesson story and share it with PRETeC, our reflection group. Three of the students who had taken part in the course had recently joined the group, and I suggested them to write a story about the same lesson so we could give a joint presentation. They read out their story first (which was my first contact with their experience). I read mine afterward. It was interesting to discover these students' point of view about a lesson that we had experienced together. The first point that they mentioned was the use of modeling clay. A colleague (a teacher educator specialized in didactics who also taught in schools) pointed out that he would never dare to do that in his lessons (in a traditional university setting), although he felt that “taking that risk was a powerful thing”. I confessed that I shared his misgivings that the task would become “infantilized” and that the expected learning outcomes would not be met. However, one of the students stated: “The teacher’s risky choice… gives me confidence, because if someone so experienced has those fears, I mean, I could do that too (…) if she did it, then I’ll be able to do it as well, so it’s like she’s leading by example” (SP-E).

We then discussed what the students had learned. In the disciplinary field, even though they reported having studied systems in many biology courses, they noted that they had never examined the connections among them: “(…) we knew all that, but we didn’t know how to apply it, for instance, our knowledge about the connection between the respiratory and the excretory systems”; “without an activity like this, we would have gone on thinking that everything was isolated, and we would have taught our students that” (SP-E). With respect to teaching knowledge, they valued being shown that simple materials could be used to generate learning.

Lastly, I tried to express what made me pluck up the courage to conduct this activity:

> I think it’s trust (…) I realize I’m developing a sort of generic trust in other people’s knowledge (…). I now think my role is to get the ball rolling and let them [students] play with it. I step aside, and point out a few things. It’s like being a mirror, something like that... not just me giving things to them (SP).

In this context, after a long discussion about teaching models, and remembering another lesson we had covered in the previous session, a colleague pointed out that this constituted a “*Pretequian*[3] teaching model”, which had two fundamental parts: teachers’ *trust* in students (and in ourselves as teachers) and (as a result of said trust) the fact that students were the ones required to *do things*. This colleague also invited us to finish the session with this question: “*How much do we trust? Do we trust our students or not? Is it necessary to know our students to trust them?*” The session ended with the following exchange:

> T1: The kamikaze-like part of the Pretequian model is to trust students before getting to know them... I think that’s a key aspect.
> T2: I don’t think it’s a suicidal choice. I don’t think it’s risky. It’s a strategy.
> T3: Couldn’t it be that we’re trying to implement a more humane way to teach? …

PRETeC, for Corina and me (Paulina), is a group that also works based on trust. This is a space where we can all share our classroom experiences using lesson stories that we read to each other and then discuss as a group. In that context, we give one another, freely and lovingly, all the recommendations and feedback that we deem relevant (even some critical comments), because we believe in the power of reviewing our experiences, not only individually but also with others in a space where everyone can learn.

Discussion

This study had a dual aim: first, to understand the practical implications of working with big ideas and to determine how this approach can contribute to the initial education of preservice science teachers. Second, we sought to understand what we had learned (in our capacity as teacher educators) about the implications and conditions that make it easier to work with big ideas, while also attempting to identify the aspects that proved to be key in this learning process.

Regarding the first point (how to work with big ideas), we can state that a big idea can be constructed with the students in the classroom by generating little big ideas derived from the analysis of concrete examples. In this case, comparing the anatomy and physiology of various organisms enabled students to abstract the processes that take place and generate an explanation that goes beyond the specific case analyzed. Also, these little big ideas were sequentially linked to each other, which made it possible to generate a framework for understanding

3 A view that characterizes PRETeC, our reflection group.

the Big Idea: in this case, living organisms' need to obtain matter and energy and their various mechanisms for doing so. Once the big idea has been constructed, it must be applied. In the case described, this involved inventing an animal, which forced the students to integrate all the previous little big ideas. This is consistent with the literature on the relationship between big ideas and learning progressions. In this regard, the former provide a powerful system of scientific explanations about the world around us, while the latter refine our understanding of the big idea by allowing us to visualize it as an interconnected network (Plummer & Krajcik, 2010). In our view, the present study brought us nearer to constructing this interconnected network of [little] big ideas, thereby refining the big idea not only for our students, but also for ourselves.

With respect to the students' learning outcomes, they gained a much more integrated understanding of living organisms and the systems that make them viable, which remedies the main errors derived from the typical approach to the teaching of this topic. To a certain extent, and in line with the points advanced by Maturana and Varela (1984), the activity highlighted the importance of seeing living organisms as systems and noting their resemblance to society in order to understand biological knowledge as an interconnected network applicable to other contexts.

As for the second aim (focused on our own learning), we learned that clearly identifying the big idea to be taught enables us to teach less planned/rigid lessons that are more directly linked to students' emergent needs (or just more flexible). Setting out to teach a big idea allows us to take risks. This flexibility enabled us to understand how important it is to listen to students and, above all, trust them. This is in line with the views expressed by Mitchell et al. (2016), who suggest that teaching approaches based on the big ideas of science are pedagogically powerful for teachers, since they enable them to attain a deeper understanding of the content and establish links between activities; in addition, they can be useful for interconnecting topics belonging to a variety of scientific disciplines (Cartier & Pellathy, 2009).

Being able to share our experiences with colleagues and students enabled us to visualize lessons from other perspectives. This *hybrid learning space*[4], which we share with teachers with a variety of levels of experience and training, is essential and vital when it comes to learning from practice. The hybrid learning space also functions as a platform where practical knowledge and theoretical knowledge converge, where the knowledge of a variety of communities is negotiated, and where a new discourse emerges in connection with the theory-practice link, which could be regarded as a new understanding (Moje, Ciechanowski, Kramer, Ellis, Carrillo, & Collazo, 2004, with respect to the "third space").

With respect to the self-study process itself, it is necessary to highlight the importance of keeping a record of the events observed and of the reflections generated, complemented by pictures of student work and classroom discussions as expressed on the board. Similarly, having a critical friend with whom to discuss the lessons makes it possible to engage in a permanent conversation, a sort of mirror that encourages one to reflect in ways that are impossible to replicate in isolation.

Conclusion

We wish to stress two relevant elements that emerged from our discussions about teaching practices (Corina in the classroom; Paulina in her PhD program). First, how practice-theory dialog has allowed us to reach a new understanding of the teaching of big ideas and of educational settings (both initial and continuing). Second, the inclusion of emotions in the classroom, which is something that we have gradually learned thanks to PRETeC and in our own professional relationship. This has had an impact on our lessons (Corina) and research proposal (Paulina). Finally, the act of reviewing, reflecting on, sharing, and discussing our practices has caused us to reassess our role as researchers and teacher educators. This, we hope, will influence our work in connection with research on science teaching in Chile.

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4 A concept that I (Paulina) coined as part of my PhD studies together with Corina and another colleague.

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