LEADING ARTICLE

# THE "GOLDEN KEY": A NOVEL APPROACH TO TEACHING/LEARNING BIOLOGY IN A SECONDARY SCHOOL IN BRAZIL: A CULTURAL HISTORICAL ACTIVITY THEORY APPROACH

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ABSTRACT

The importance of developing students' conceptual understanding of biological science in school is well established as a precursor to future development (Cachapuz et al. 2005). However, students continue to underperform in this important scholastic area due in large part to not engaging in the deeper concepts taught. In this article we investigate an interdisciplinary approach to teaching biology in a school in Brazil. We draw on the theoretical concepts provided by Cultural Historical Activity Theory (CHAT) to unpack how interdisciplinary teaching, across different activity systems, can lead to shifts in the activity systems, with students developing a deeper conceptual understanding of biology. Seven teachers (from chemistry, biology, the arts, and geography) and 196 students form the participants in this study. Findings indicate that contradictions arising both within and between activity systems across the teaching contexts led to students' object shifting from merely covering the curriculum to developing a deeper understanding of biological concepts.
**Keywords**: Cultural Historical Activity Theory, case study, high school teaching, biology lessons

> "In the end we will conserve only what we love; we will love only what we understand; and we will understand only what we are taught." (Baba Dioum 1968, 28).

## INTRODUCTION

The teaching of Biology in High School is of great importance in the sense of the development of scientific education as a requisite for the formation of thinking and production of responsible citizens in the decision-making around emerging and increasingly complex socio-scientific problems. According to Cachapuz et al. (2005), "scientific education ... makes possible future development", and constitutes "an urgent requirement, an essential factor in the development of people and civilizations" (Cachapuz et al. 2005, 9). However, some teachers report high school failure in this area, low scholar engagement and a general lack of enthusiasm for learning scientific subjects (Giordan 1997; Furió e Vilches 1997). Considering the importance of scientific education for future development, this research sought to investigate whether an interdisciplinary approach to teaching biological concepts would impact on students' engagement with the subject and improve their understanding of biological concepts. The question driving this article, then, is "can a novel, action based, interdisciplinary approach to teaching biology shift students' engagement with the concepts taught"? To unpack this question, we draw on the theoretical resources provided by CHAT.

## LITERATURE REVIEW

The question driving the literature review related to the use of Cultural Historical Activity Theory and the teaching/learning of Biology in high school. The review limited itself to the period of 2000–2019, as we wished to report on teaching/learning in the 21st century. The following steps were followed to retrieve data: First we searched only English data bases as the first author is an English first language speaker. These included, ERIC, EBSCOHOST, HUMANITIES INTL, JSTOR and Education. Studies were selected based on the following criteria:

1. They utilised a CHAT or Vygotskian framework to study Biology teaching/learning
2. They were focused at a school level, rather than a tertiary level
3. They fell between 2000–2019.
4. They were in peer reviewed journals/books.

We decided against selecting grey literature and unpublished works as we wished to reflect what is currently published in the field. There was a dearth of published studies that utilised CHAT as a framework for discussing Biology education. We could locate only 3 studies in this field, two of which reported results from higher education and were, therefore, excluded from the review. A notable exception is the work of Roth and Lee (2007) whose detailed article forms the major basis of this review. While there is a large body of research using Vygotsky's (1978; 1986) work in mathematics (for example, Barwell 2016; Bozkurt 2017; Lerman 2001; Venkat and Adler 2008), teaching with technology (Kaptelinin 1997; Kuuti 1996; Lakkala, Lallimo, and Hakkarainen 2005; Lakkala, Muukkonen, and Hakkarainen 2005; Lim 2001; Lim and Hang 2003; Lim and Chai 2004) and studies in language (Mercer, Wegeriff, and Dawes 1999; Mercer 2000a; 2000b; Mercer and Kleine Staarman 2005; Mercer 2010) there is little evidence that this work has been used to study teaching/learning in Biology. While explicit reliance on the work of Vygotsky, or the Neo-Vygotskian development in CHAT is absent from the literature, we note that we found 8 articles that speak to biology pedagogy as “constructivist” (Lin 1998; Ah-Nam and Osman 2017). The basic premise underlying social constructivism is that individuals are active cognising agents, who actively engage with the world during problem solving altering both themselves and the world as they do so. This understanding derives from Vygotsky (1978). However, while many people may suggest that Vygotsky was a social constructivist (and indeed many introductory textbooks in educational psychology say just this) we feel that the notion of “constructivism” has come to mean a number of things; not least of which is that the environment is entirely responsible for the development of higher order thinking. This takes us too far away from Vygotsky’s developmental project and is based on a dualist, rather than dialectical view of development. More problematically, we argue, is the fact that constructivism in science and biology teaching has been linked to discovery-based learning, where children are left to “discover” the knowledge as they engage with problem solving. We argue that this is highly problematic because it leads to children constructing misconceptions about the natural world (Karpov 2005). Appearances can seriously mislead a child. Take for example the following: a child is asked why certain things float while others sink. The teacher places a piece of brown wood in water, and it floats; brown cork, similarly floats. Empirically, it appears to the child that the colour brown is responsible for making things float. This of course, is a misconception. The review of the literature, then, leaves us essentially with Roth and Lee’s (2007) paper which is entitled “Vygotsky’s neglected legacy: Cultural Historical Activity Theory” and this title is indeed apposite in relation to Biology teaching as there is a paucity of published work that uses CHAT to analyse teaching/learning in a science-based environment. The paper traces the trajectory of CHAT from Vygotsky’s work through to Engeström’s more recent developments of the theory. What is of particular interest for us is the use of an empirical example in which children problem-solve in relation to a real-world example of pollution; their creek. What Roth and Lee (2007) illustrate is how CHAT can be used to track the contradictions that arise in practice and how these contradictions can be met, leading to new object. In our own work discussed below, we indicate a similar scenario. We turn now to a more detailed theoretical exposition of CHAT.

## THEORETICAL FRAMEWORK: CULTURAL HISTORICAL ACTIVITY THEORY AND TEACHING/LEARNING

### From dualist to dialectical logic

Since Descartes articulated his famous “Cogito ergo sum” in the 17th century, Western philosophy has been essentially dualist in its logic with binaries set up between, for example, the individual/social and mind/body. Following on the work of Hegel as it is recontextualised in the psychological approach of Vygotsky (1986), we adopt a dialectical logic to understanding development, focusing on how mind is necessary always social and calling into question the false binaries of individual/social. In his general genetic law, Vygotsky suggests that:

> “Every function in the child’s cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formulation of concepts. All the higher functions originate as actual relations between human individuals.” (Vygotsky 1978, 57).

What we can see from this quote is that mind and society are dialectically linked; one cannot conceive of the one without the other. This is the logic that informs the view of pedagogy that we describe below.

In this article we understand pedagogy as mediation within the Zone of Proximal Development (ZPD) by a more competent peer (generally a teacher) of a novice. This definition draws on the body of pedagogical knowledge arising from the work of Vygotsky (1978). Here mediation refers to structured guidance in a problem-solving situation where a culturally more advanced “other” guides the novice to solve the problem in a uniquely social space called the ZPD. This space is opened in dialogical interaction between teacher and taught and is described by Vygotsky as:

> “... the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers ... the actual developmental level characterises mental development retrospectively, while the zone of proximal development characterises mental development prospectively.” (Vygotsky 1978, 86–87).

It is in this unique social space that development can happen given the necessary mediation. Mediation in the ZPD is geared towards the acquisition of scientific or schooled concepts. Vygotsky (1986) makes a distinction between every day, spontaneous concepts, and scientific or schooled concepts that are necessarily taught. For Vygotsky, the scientific concept is

> “..., a phenomenon that occurs as part of the educational process, constitutes a unique form of systematic co-operation between the teacher and the child. The maturation of the child’s higher mental functions occurs in this co-operative process, that is, occurs through the adult’s assistance and participation. ... In a problem involving scientific concepts, he must be able to do in collaboration with the teacher something that he has never done spontaneously ... we know that the child can do more in collaboration than he can do independently.” (Vygotsky 1987, 168).

The quote above illustrates that the teaching of a scientific concept happens within the ZPD, or that space where guided assistance serves a developmental purpose.

While distinct, scientific and everyday concepts are dialectically entailed; one cannot understand abstract concepts such as schooled concepts in the absence of everyday, or spontaneous concepts and spontaneous concepts are only fully actualised through scientific concepts (Daniels 2001). It is important to note here that “scientific” concepts do not refer solely to concepts in science but rather, to all schooled concepts that are abstract and need to be explicitly taught. Vygotsky’s work was developed further by Leontiev (1981) who situated individual action within the larger collective activity, articulating the need to understand the activity in which actions play out. An activity is motivated by an object or need state to which collective activity is then geared. This work in turn was developed further by Engeström (1987) who studies human action as an activity system in which various nodes of the system influence how an individual or group acts on an object. Engeström’s Cultural Historical Activity Theory (CHAT) is capable of situating pedagogy in the context in which it unfolds (Kuutti 1996; Lim 2001; Lim and Hang 2003; Lim and Chai 2004).

In this article we draw primarily on the work of Engeström’s 3rd generation cultural historical activity theory (CHAT) (see Figure 1). In Figure 1 we can see a current version of an activity system in which individual actions play out in a collective activity (Engeström 1987; Engeström, Miettinen, and Punamaki 1999). The subject, acts with mediating artefacts on the object, which is transformed through the activity into an outcome. This happens in a context in which rules mediate between the subject and tool use and division of labour, or the roles enacted, mediates between the community and the object being acted on. The community represents those people who share an object. For clarity, in this article the subject across the activity systems is the teacher who acts on the object, which, for teachers is the development of students’ biological understanding. This takes place in a context where roles (division of labour) differ, with the teacher generally seen as in a position of power in regard to the knowledge being acquired. The object is the motive for the activity and can be seen as the problem space that is transformed throughout the activity. The teacher(s) act on the object of the activity using various tools, such as concepts or, in this study, practical environmental artefacts to transform the object. It is disingenuous to suggest that students necessarily share the same object as teachers do. Indeed, students' object might be nothing more than passing the course in order to graduate and have nothing to do with developing his/her own biological concepts. We investigate this in the article. The community in the diagram below are those members who share a common object; in this case, it is several teachers across a number of disciplines who share the object of developing students' biological concept knowledge. While students are also part of the community in the activity system, as we have noted, we cannot necessarily assume they share the same object as the teacher.

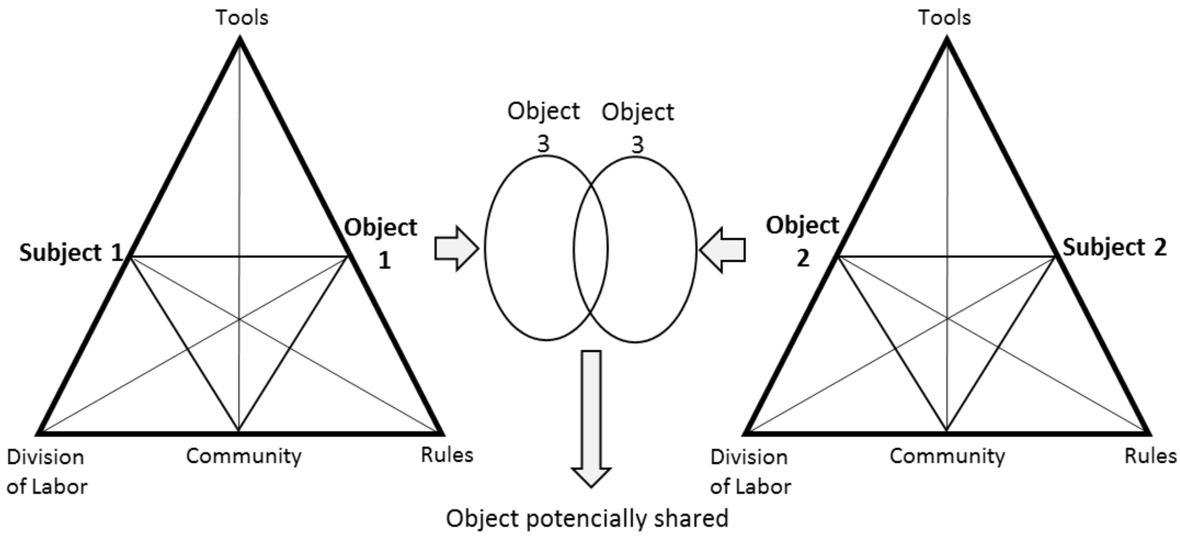



**Figure 1:** Two interaction activity systems (Engeström 1987, 120).

## CONTRADICTIONS

Engeström refers to contradictions, or double binds, that arise both within and between activity systems. These spaces of dissonance should be seen not as problematic but rather as instances of dynamic change. Where a contradiction arises, the actors will try to overcome this. It is important to note, however, that contradictions can lead to progress, but they can also lead to a regression of the system to a more traditional model.

## CHAT AND THE PEDAGOGICAL MODEL IN THIS STUDY

The understanding of teaching/learning as dialectically entailed informs our CHAT approach to designing the instruction in this study. What this means, is that we understand that learning must be appropriately mediated by a more competent other, in the students' ZPD. In Engeström's elaboration of CHAT, the interacting activity system is the smallest unit one can study in order to make sense of what is happening in the teaching/learning space. Moreover, the notion of "object", that space that motivates the activity and which is worked on and changed through the actions within the activity system, provides us with a mechanism for understanding how students approach a given task in each context. Our teaching intervention aimed to provide an authentic learning space for the students that was different to the traditional chalk and talk methods of the face-to-face lesson. In a traditional teaching session, division of labour locates power within the teacher, whereas the students' role becomes one of passively absorbing the knowledge "transferred" by the teacher. We wanted to achieve a more symmetrical power relation between teacher and taught, by recruiting students' understandings of the problem under study. When planning this intervention, therefore, we attempted to use real life, authentic problems to engage students in. We aimed to try to break down asymmetrical power relations so that the community, that is the teachers and the students, could have access to constructing a meaningful object together. This necessitated changing the rules that are present in a classroom, such as putting up your hand to ask a question or taking talk time from the teacher. Our mediated means were practical, real-life examples of the Animalia kingdom, in their actual habitat. What follows is our analysis of how this intervention, informed and underpinned theoretically by CHAT, impacted on the students' object and outcomes in this course.

## BIOLOGY TEACHING CONTEXT

The research was carried out with third year high school students, whose curricular biology content is constituted by a block on Living Beings that include all the organization and classification of these living beings into five kingdoms. The Animalia Kingdom, presents the largest portion of the content and it is this knowledge that was selected as the basis of the teaching intervention reported in this article. This content includes morphological, physiological, and ecological animal aspects and demands learning several new names and concepts, which makes this topic potentially boring and tedious for students when taught in a didactic, lecture style manner. Moreover, students do not know many of the concepts studied in the classroom since they are removed from the students' every day, lived experience. Thus, by not appropriating the meanings immersed in the new names and concepts, they do not attribute a meaning to learning such content. Failure to understand the meaning of the concepts in any real depth, leads to students' being motivated solely by the desire to pass the test, rather than to develop a deep understanding of biological concepts. That is, students' objects differ from the teachers' stated object: to develop students' conceptual understanding of biological terms and concepts.

A consequence of students’ motive to merely pass a test means that rather than developing higher cognitive functions, students rely on rote memorization in order to achieve their object of passing the test. The students’ object, then, is mere performance in order to obtain a good test score, rather than deeper understanding. We have seen this in earlier research carried out in South African classrooms (Hardman 2015) where the object of mathematics learning for students is test success rather than deeper conceptual understanding. What this leads to is frustration both for the students, who study a large corpus of knowledge without deriving meaning from it, and for the teacher whose object is not met. It is this problem that led to the study on which this article is based. In a bid to develop students’ conceptual understanding of biology and to therefore, shift their object, the biology teacher proposed a unique interdisciplinary teaching sequence that involved both traditional lessons as well as less traditional field trips and a novel assessment which we call the gymkhana. Teachers were introduced to Cultural Historical Activity Theory as a mechanism for understanding their practice in two workshops, which took 4 hours each. In these workshops, the researchers outlined CHAT, before illustrating how they would use it as an analytical lens through which to study pedagogical practices. The notion of the object as a space that needed transformation was surfaced in these workshops by the teachers and the researchers working together to ascertain what the object of teaching *should* be; that is, the developing of an understanding of biological concepts. During the workshops, we worked with teachers to encourage an approach to teaching that included students’ voices and the development of authentic problems related to real life experiences that students could engage with. We illustrated to teachers how scientific and everyday concepts are dialectically entailed and how the object of an activity must contain both the sense and meaning of the activity. That is, the meaning is a general, shared meaning between students and teachers while the sense, referred to here is related to students’ idiosyncratic everyday concepts.

In the present article we try to understand and analyse a biology teaching sequence, which was developed over three consecutive years (2013–2015) in a Brazilian public school. The teaching sequence was performed in three main steps: 1) the planning phase with meetings between the teachers; 2) the interaction phase between teacher and student, which included the theoretical classes, laboratory classes and field trip; and 3) a final evaluation phase.

These three phases of the biology teaching sequence and their activities are described in a following table (Table 1) and are discussed.

**Table 1:** Detailed steps of biology teaching sequence performed in a Brazilian public school.

| Phases of teaching sequence | Activities of teaching sequence | Description of activities of biology teaching sequence |
|---|---|---|
| Planning phase | Teacher meetings | The teacher teams met several times and planned the activities over a 5-month period. Individual and joint actions were planned which happened during the three steps in the interaction phase in order to connect different subject content matter in a complimentary manner. In this planning phase the teachers decided together both what and how they would teach, as well as choosing the appropriate tools for meeting their object. This process was underpinned by a CHAT design. |
| Interaction phase | Theoretical classes | The initial teaching between teacher/student was in a traditional classroom, inside school, using a white board and textbooks. It is at this point that the students' knowledge level about the subjects was verified and biological concepts were introduced. This initial step was found to be important in introducing students to biological concepts that they would then learn more about in field and laboratory settings. |
| | Laboratory classes | Teaching here took place in the school laboratory using models and with animals *in vivo* and *in vitro* obtained by university donations or bought in fish stores or from fishermen. This happens simultaneously with the theoretical classes and it was a opportunity for students observe, touch and do experiments. |
| | Field trip | The field trip was carried out at Enseada das Garças beach (district neighbourhood of Praia Grande) Fundão City – ES. The beach is part of *Costa das Algas* Environmental Protection Area, a marine conservation unit created by the Federal Government and managed by Chico Mendes Biodiversity Conservation Institute, with defined rules for fishing, tourism and beach occupation. Therefore, it is not visited often and there are neither kiosks nor bathers on the beach. This class spent one day at the beach and it consisted of investigating specimens' behaviour through observing them in their natural habitat, as well as some monitored practices. |
| Evaluation phase | Gymkhana | This consisted of a game of questions and answers about the subject matter content covered thus far in the classroom. For this step, the class was divided into five groups of five students each. The correct answers were tallied up as points and awarded to the winning group, who were then exempt from taking the formal written test. Exemption from a formal test was introduced to motivate students to learn the concepts in more depth, rather than in a rote manner. |
| | Test | This test was the last one of the first semester and it had a cumulative character; in other words, in this test all the content studied in the first semester of the year were tested. It was an objective test with 50 questions. |

## METHODOLOGY

The study reported here follows a case study design (Yin 1981) and is based in a qualitative methodology because it seeks to investigate how alteration to traditional pedagogical practices impacts on the object of learning. All students and participating teachers gave consent to participate in this study and ethics clearance was obtained from the university's School of Education ethics committee. Permission to conduct the research in the school was obtained from the school district. Students were given consent forms to participate in the study. They were told they could withdraw at any time should they wish to. The following data were collected:

- Teachers reports on their teaching.
- Video data of pedagogical contexts

- Photographic data of pedagogical contexts
- Student questionnaires that sought to elicit students' perceptions of the novel pedagogical method in their subsequent outcomes.

## PARTICIPANTS

The subjects in this study were a group formed by the biology (1 teacher), chemistry (2 teachers), physics (1 teacher), geography (2 teachers) and arts teachers (1 teacher) and 196 students in the third class of high school in a public school located in Vitória – ES, Brazil. This is a regular school located downtown and the students come from several neighbourhoods. The teaching activities were initiated by the biology teacher who wanted to change pedagogical practices and develop students' motivation to learn concepts in biology.

## ANALYSIS AND DISCUSSION

The proposed interdisciplinary activity adds complexity to teaching, since it increases the number of subjects involved in this activity. Rather than one teacher involved in the activity, an interdisciplinary team worked together to teach the concepts, leading to an interaction between various activity systems. Five activity systems worked together on the shared object of developing students' understanding of biological concepts. Analytically, each system can be represented as a single system; however, in this project, the systems interacted with one another, forming a collective activity. Below we discuss the separate activity systems before presenting them as interacting systems.

### The theoretical class

The first activity system described is that of the traditional classroom. The Brazilian education system still adopts a passive transmission pedagogical approach, in which students are forced to sit quietly and "absorb" knowledge, which is "transferred" from their teachers. Many authors report that "didactic" classes are still teachers' predominant pedagogical strategy (Hoadley 2017). This leads to students' lacking motivation to engage with the deeper concepts.

In Figure 2, we can see that the subject is the teacher who works on the object of students' understanding of biological concepts. However, students do not share this motive and hence, the outcome is not the development of biological concepts, but rather the representation of these concepts on a test. There is, therefore, a contradiction in the object between student and teacher; this contradiction narrows the students' outcomes to one of mere memorisation, rather than leading to the development of a deeper understanding of biological concepts.

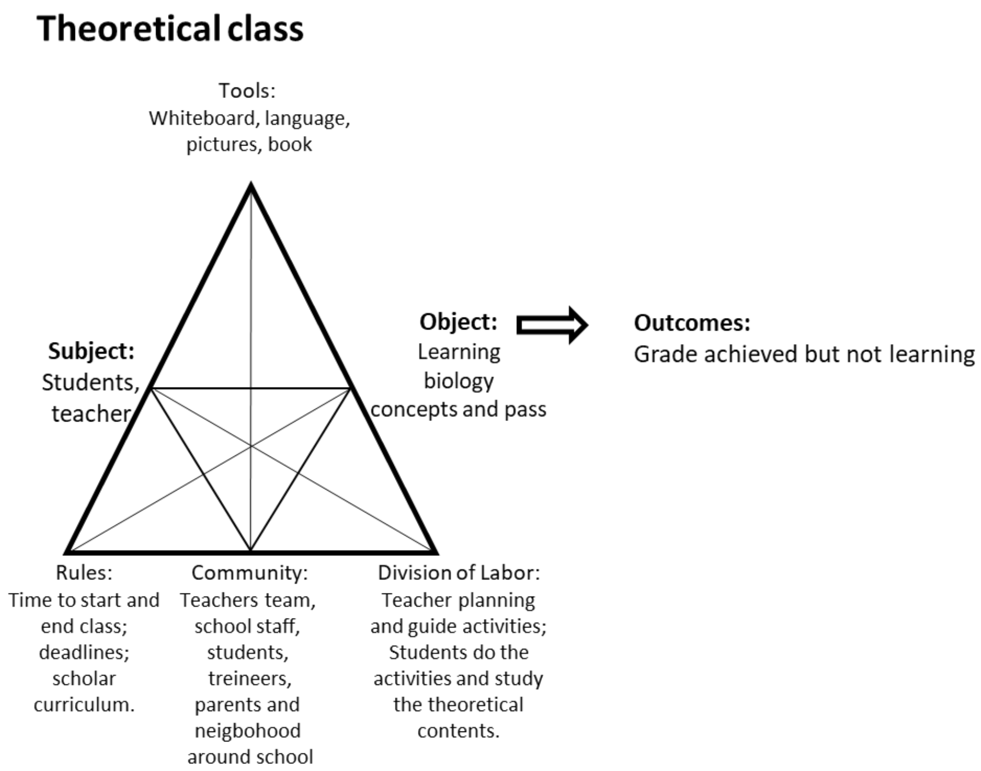



**Figure 2:** Activity system of theoretical class

## The laboratory lesson

The school’s science laboratory was shared by biology, chemistry and physics teachers working in shifts, with some teaching in the morning, afternoon, and evenings. The laboratory is located in an old school basement and cannot accommodate the entire group of students. For this reason, classes were split into two groups or, when this was impossible, biological materials were carried to the theoretical classrooms in trays.

Although there were difficulties, this class was eagerly anticipated by the students, because it was the moment that the students had visual and manual contact with the animals discussed in theory. It was possible to observe morphologic characteristics highlighted in theoretical classes and then discuss their functions. In addition to the observation, the students could also touch animals to feel their texture, firmness and other characteristic aspects.

In Figure 3 we see that students are more engaged with the learning in the laboratory as it links to their everyday learned experiences. Hence, the outcomes are learning, rather than the mere regurgitation of knowledge on a test article.

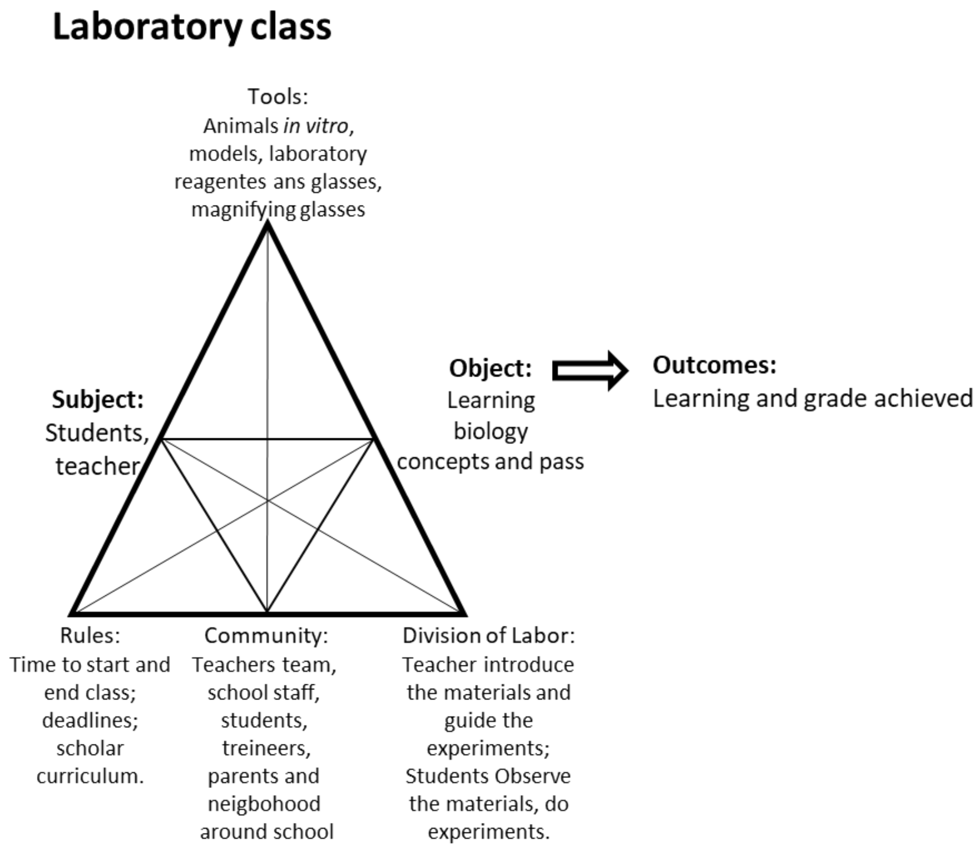



**Figure 3:** Activity system of laboratory class

## The field trip

All teachers from the different subject areas were involved in the field trip with the students. The field trip provides the opportunity to observe living organisms in their own habitat; it is, therefore, an authentic engagement with abstract biological knowledge. In the marine ecosystem the fauna, flora, geographic, chemical and physical aspects of the area were observed. The following themes were explored: 1) morphological and functional aspects; 2) ecological distribution and interaction of organisms, including with humans; 3) quality and chemical and physical characteristics of sand and sea water; 4) dynamic tidal and moon movements; 5) geological and ecological characteristics of coastal and mangrove ecosystems, their location, fauna, flora, socio-economic importance, impacts and environmental laws, in addition; 6) specific local issues related, for example the reality of a society economically dependant on these ecosystems, such as, the crab collectors, the fishermen, and the clay pan producers of the region.

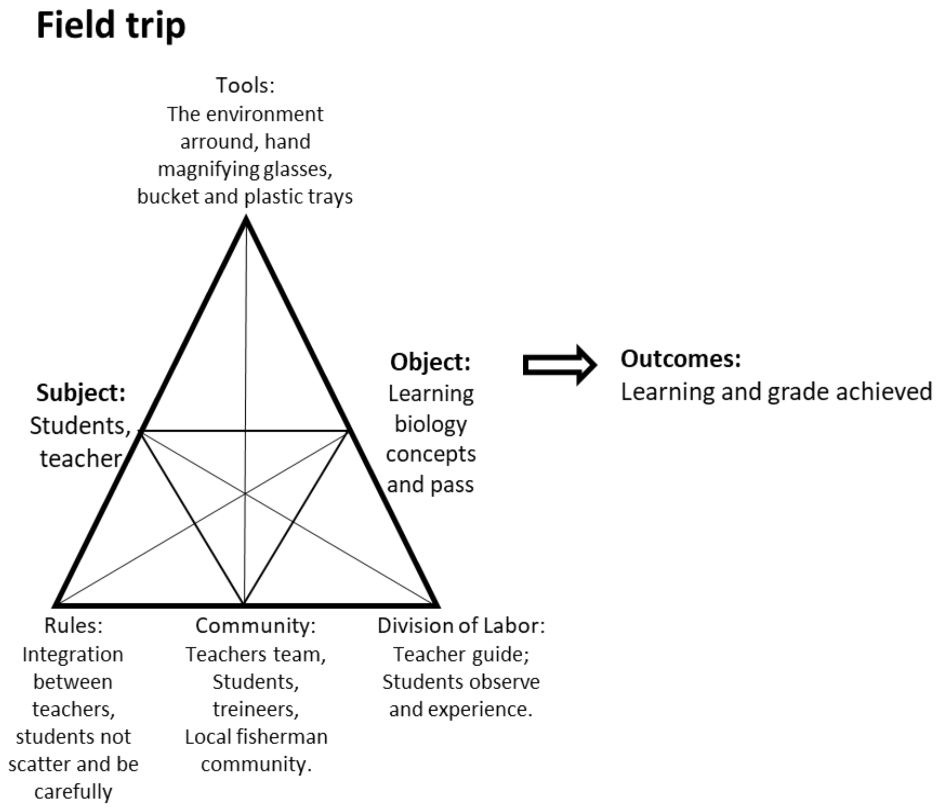



**Figure 4:** Activity system of the field trip

It is in the field trip that we truly see students’ object shift to the understanding of biological concepts. That is, it is here that the motive of teacher and student coincide. We noted earlier that the optimal conditions for acquiring scientific concepts lies in the linking of these to everyday, spontaneous concepts. It is here, in the field trip, where the students can view biological concepts in context, that the link between the abstraction of the theoretical concepts and the reality of their everyday experience of organisms can develop deep conceptual knowledge. Division of labour becomes more symmetrical with the teacher taking on the role of guide, rather than “knower”. This is borne out in students’ responses to a questionnaire they were given.

In the Figure 5A most students said that they did not feel curious in the theoretical classes, but in laboratory classes (38%) and in the field trip (54%) they were very curious because they were more engaged. While in the class students’ object is test success, in the laboratory class and the field trip their object changes, to a curiosity to know and understand the concept in its context and the outcome is consequently the learning of biological concepts. Students indicated that they felt more learning had taken place in these activities (Figure 5B).

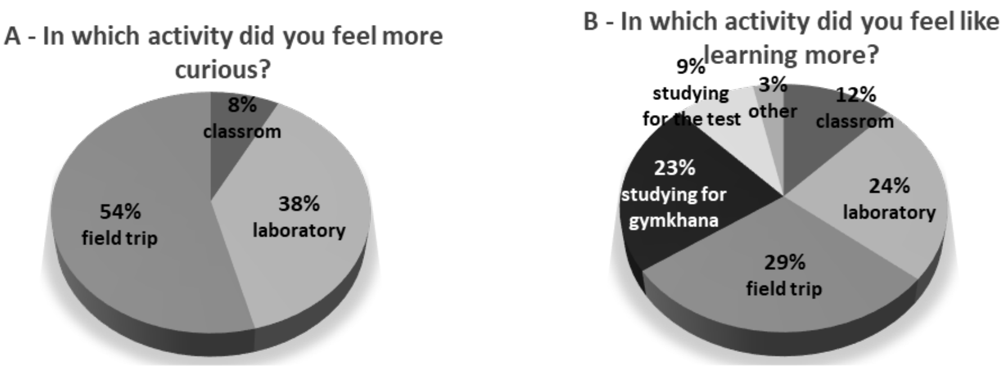
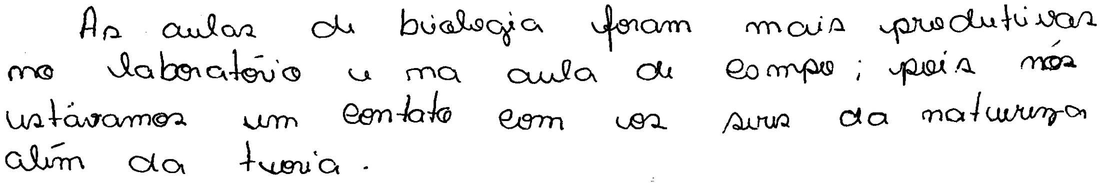
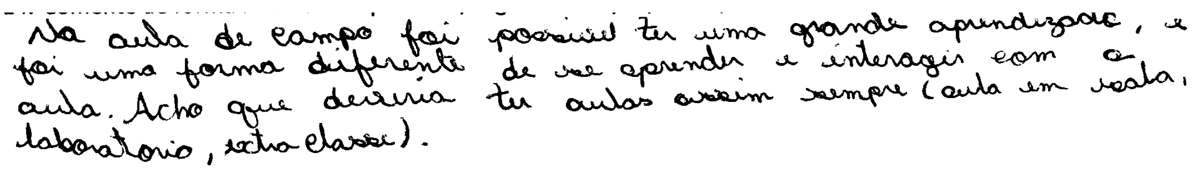



**Figure 5A and B:** Percentage of student’s questionnaire answer after the Marine Biology activities.

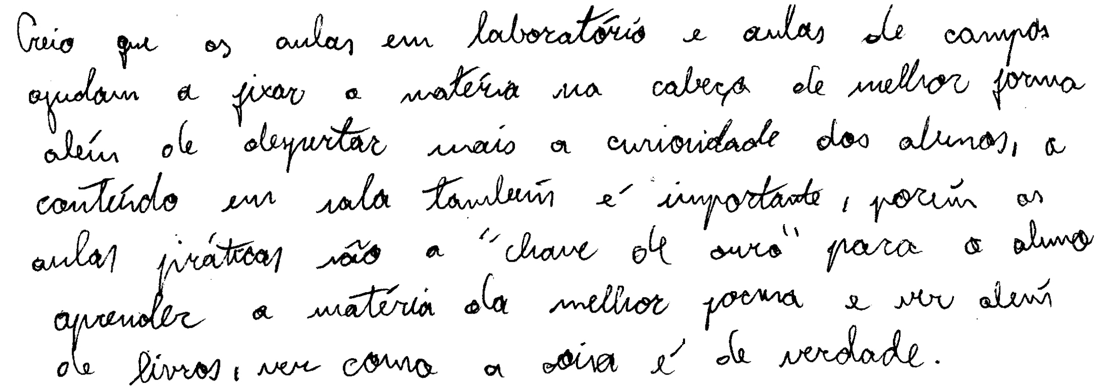
This is further illustrated in their questionnaire responses, where students indicated that they were more engaged with the field and laboratory setting than the traditional classroom.


As aulas de biologia foram mais produtivas no laboratório e na aula de campo; pois nós estávamos em contato com os seres da natureza além da teoria.

> “The Biology classes were more productive in the lab and in the field class, because we were beyond the theory in contact with nature beings.”


Na aula de campo foi possível ter uma grande aprendizagem, e foi uma forma diferente de se aprender e interagir com a aula. Acho que deveria ter aulas assim sempre (aula em sala, laboratorio, extra classe).

> “In field classes, it was possible to have a great learning and it was a different way to learn and interact with the class itself. I think there should always be classes like that (class in classroom, lab, extra class).”


Creio que as aulas em laboratório e aulas de campos ajudam a fixar a matéria na cabeça de melhor forma além de despertar mais a curiosidade dos alunos, o conteúdo em sala também é importante, porém as aulas práticas são a “chave de ouro” para o aluno aprender a matéria da melhor forma e ver além de livros, ver como a coisa é de verdade.

> “I believe the lab and field classes help to fix the content in mind better, besides they turn on the students’ curiosity, the class content is also important, but the practical classes are the ‘golden key’ for students to learn the subject in a better way and to see beyond the books, seeing how the thing really is.”

The pedagogical importance of the field trip is not only reported by the students, but also by participating teachers as in the extract below:

> "The students were very excited and the learning flowed significantly in the field activity. Interdisciplinary activities where the learner can experience the field (in this case the marine environment), was clearly positive for a better learning and environmental and social awareness of the students." Chemistry teacher.

## The Gymkhana

This was structured as a game of questions and answers that tested the students' biological knowledge. This step was done with the goal to motivate the students to study the concepts taught and to do revision in a dynamic way before the test. The strategy was to involve the students to gain active participation for a collective revision of content between students and the teacher, and not, as traditionally happens, on an individual test.

The classes were divided into groups and correct answers for the biological questions scored points. At the end of game, the group with the highest score was the winner. As a reward, they were exempted from taking the test. Due to the general fear of tests, which they consider difficult, this proposed reward worked as a great motivator for the students to win the game, thus exempting them from the traditional test. It is worth noting, however, that the questions asked in the gymkhana were of the same level of difficulty as those asked in the written test. However, due to the interdisciplinary, authentic engagement with biological concepts in the field trip and the unusual nature of the gymkhana as a kind of quizz, the students felt it was easier than the written test.

What is interesting to note in Figure 6 is that students' initial motive for studying for the gymkhana is to become exempt from taking the traditional test. However, this motive changes to one of actual learning of biological concepts as an unintended outcome of wanting to be exempt from the test: that is, students' learn the biological concepts even though that is not initially their object. There is, then, a contradiction between the teacher and the students' object. This contradiction forces a change in the students' object from being one of merely passing a test to in fact, developing biological concepts. This novel approach to testing, then, has shown how testing can alter the students' object to align with the teachers' object. As we discuss below, a traditional test is unable to achieve the same result.

## Evaluation

Finally, those students who did not win the gymkhana were required to write a traditional, summative test. This is represented as an activity system in Figure 7.

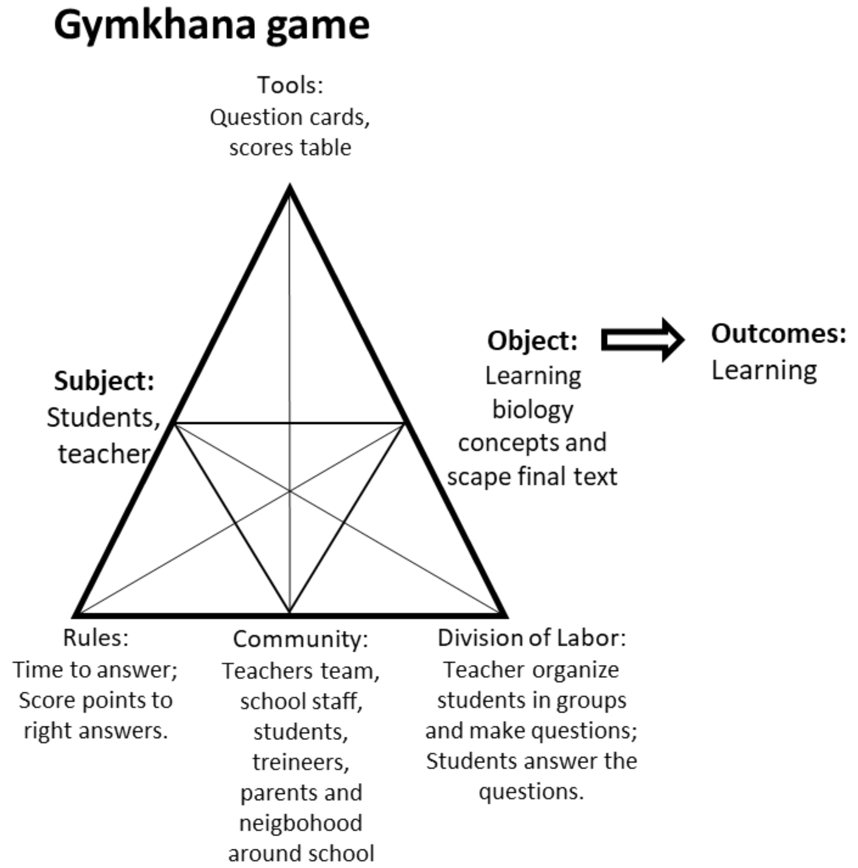



**Figure 6:** the gymkhana

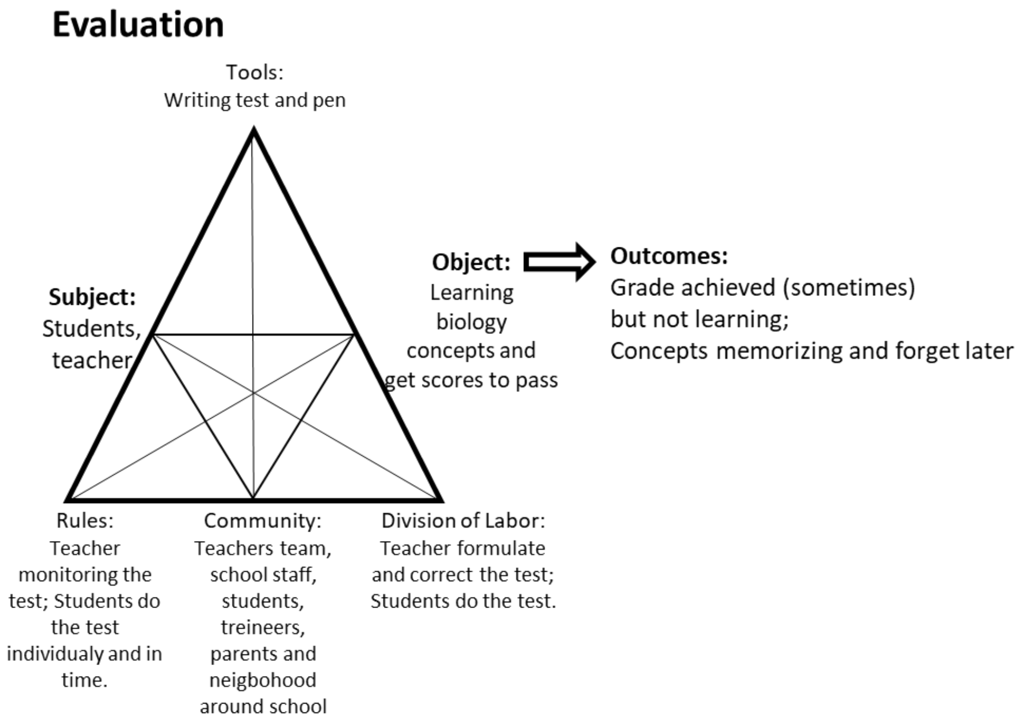



**Figure 7:** Evaluation

While the teachers’ motive here is for students to develop an understanding of biological concepts, this is in contradiction to the students’ motive, which is to pass the test. Unlike in the gymkhana, where this contradiction led to an actual growth of the object to include deep understanding, the understanding here is not developed and is represented merely as memorisation which will later be forgotten rather than leading to the development of higher cognitive functioning.

Table 2 presents a synthesis of the discussed objects, contradictions and the object changes in the five sub activity systems which compose the whole marine biology teaching sequence. If the subjects involved in the activity do not have the same motives, they will not reach the intended outcome. Contradictions were observed in the theoretical classes, gymkhana and the evaluation. However, in the gymkhana, we observe a change in the students’ motive. This novel pedagogical approach to testing, we argue, could promote this transformation in students’ objects. Table 2: Compilation of the five different activity systems comprising the biological teaching sequence with the subjects involved and their different objects, rules, division of labour and outcomes. Highlighted in bold are the contradictions and in italic bold the change of the object.

**Table 2:** The different activity systems and contradictions that arose.

| **Biology Activity systems** | **Subject** | **Object** | **Tools** | **Rules** | **Division of Labor** | **Outcomes** |
|---|---|---|---|---|---|---|
| **Theoretical class** | Teacher | **Learning** | White board, books, pen, pencil, computers | Time to start and end | Teach class | Grade achieved but not learning |
| | Student | **Get scores grade achieved** | | Chair position to sit | Students listen to teacher | |
| **Laboratory class** | Teacher | Learning | Animals *in vitro*, models, laboratory instruments, glasses, magnifying glasses | Time to start and end, organize the materials, clean the laboratory | Introduce the materials and guide the experiments | ***Learning and appropriation*** |
| | Student | ***Satisfy curiosity*** | | Chair position to sit | Observe the materials, do experiments | |
| **Field trip** | Teacher | Learning | The environ-ment around, bucket and plastic trays | Integration with other teachers | Guide the students | ***Learning and appropriation*** |
| | Student | ***Satisfy curiosity*** | | Not scatter, be careful | Observation | |
| **Gymkhana** | Teacher | **Learning** | Question cards, scores table | Score points to achieve right answers | Organize the students in groups and make questions | ***Learning*** |
| | Student | **Escape the final test** | | Time to answer | Answer the questions | |
| **Evaluation** | Teacher | **Learning** | Test paper and pen | Monitoring the test | Design and correct the test | Memorising and sometimes appropriation but not learning |
| | Student | **Get scores to pass** | | Time to do the text, do the test alone. | Do the test | Concepts memorised and later forgotten |

## CONCLUSION

This article highlights an extended teaching sequence in marine biology in Brazil. It presents a novel approach to teaching biological concepts through 1) an interdisciplinary approach to teaching and 2) a novel pedagogical and testing approach. Utilising CHAT we show that the object of students in a traditional classroom differs between students and teacher, with the teacher intent on developing deep conceptual knowledge and the student intent on passing the course through memorising information for a test. We go on to illustrate how the contradictions, those sites of potential dynamic change, arising through shifts in context can lead to a shift in the object with teachers and students both sharing the intended object of the biological teaching sequence: the acquisition of biological concept knowledge. This is illustrated best in the data in reference to the field trip where scientific and everyday concepts are dialectically meaningfully linked and, in the gymkhana, a novel testing process that leads to a contradiction in the students' object, ultimately changing it.

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