Triangular bipyramid metaphor (TBM), an imagetic representation for the awareness of inclusion in chemical education (ICE)

A Metáfora da Bipirâmide Triangular (MBT), uma representação imagética na promoção da inclusão no ensino de química (IEQ)

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ABSTRACT
Given the urgent needs we face regarding Inclusion in Chemical Education (ICE), it is ever more evident that teachers worldwide need new perspectives to provide solutions for a more accessible, critical, and assistive education process. This work aims to propose a new pictorial representation, the Triangular Bipyramid Metaphor (TBM), for the awareness of Inclusion in Chemical Education (ICE). This new metaphor is depicted as a having a triangular bipyramidal shape with five levels of instruction: (1) symbolic or representational, (2) sub-microscopic or model, (3) macroscopic or phenomenological, (4) human aspect or context, and (5) inclusion. In short, TBM was created as a new perspective of the Mahaffy's metaphor for working with students and the public. We hope that TBM could be useful for creating and developing novel solutions through interdisciplinary and comprehensive collaborations, providing new resources for ICE.

Keywords: chemical education, inclusion, systems thinking, the chemistry triplet, universal design.

RESUMO
Diante das necessidades urgentes que enfrentamos em relação à Inclusão no Ensino de Química (IEQ), é cada vez mais evidente que os professores em todo o mundo precisam de novas perspectivas no fornecimento de soluções para um processo de ensino e aprendizagem mais acessível, crítico e assistivo. Neste trabalho, objetivou-se apresentar a Metáfora da Bipirâmide Triangular (MBT), uma representação imagética para maior conscientização da IEQ. Esta nova metáfora é retratada geometricamente como uma bipirâmide triangular com cinco diferentes níveis: (1) simbólico ou representacional, (2) microscópico ou teórico, (3) macroscópico ou fenomenológico, (4) elemento humano e (5) inclusão. Criativamente trata-se de uma nova perspectiva do tetraedro de Mahaffy. Espera-se que a MBT seja didaticamente útil para criar e desenvolver soluções por meio de colaborações interdisciplinares e abrangentes, fornecendo novos recursos para a IEQ.

Palavras-chave: educação química, inclusão, pensamento sistêmico, triângulo de Johnstone, design universal.

1 INTRODUCTION

> "We cannot solve our problems with the same thinking we use to create them"
> Albert Einstein

Given the urgent needs we face regarding Inclusion in Chemical Education (ICE), it is ever more evident that teachers worldwide need new perspectives to provide solutions for a more accessible, critical, and assistive education process. While there are many modern publications on the comprehensive approaches to ICE - such as the special issue of the Journal of Chemical Education for Diversity, Equity, Inclusion, and Respect in Chemistry Education Research and Practice [1] – we have the opportunity to recognize the previous shortcomings in science education and to provide new resources for ICE.

In the early 1980s, Alex H. Johnstone proposed a triangle of thinking levels in chemistry: the macroscopic (description), submicroscopic (explanation) and symbolic (representation) levels [2–4]. According to Johnstone (1993, p. 703):

> The new chemistry has three basic components: microchemistry, submicrochemistry, and representational chemistry (…) Much of the old chemistry was concerned only with the macro and representational corners and shared edge. The submicro, structural part was often missing and so the middle of the triangle never was explored. (JOHNSTONE, 1993, p. 703)

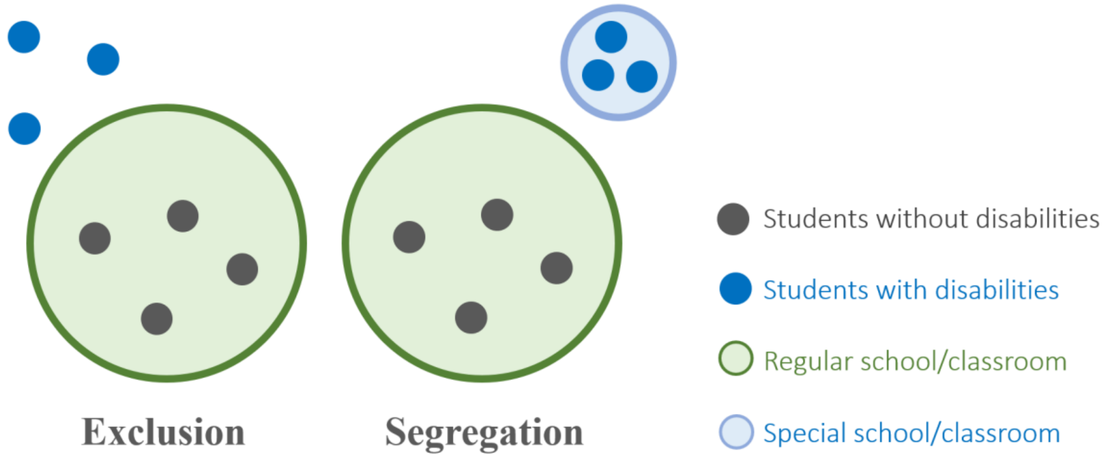
The Johnstone's triangle has been documented in several publications in literature [5–12]. In the 2000s, Peter Mahaffy adapted that triangle model into a tetrahedron or a triangular pyramid, where the fourth vertex represents the human contexts for chemistry [13,14]. Mahaffy proposed a new conceptual metaphor that enriched our understanding of Chemical Education (CE). Numerous recent works have discussed, applied or adapted his tetrahedral model [15–18].

Building on the Johnstone's triangle and the Mahaffy's tetrahedron, it was realized that inclusion was not part of Chemical Education (CE). An improved metaphor is necessary to guide innovative approaches and connections. This work aims to propose a new pictorial representation, the Triangular Bipyramid Metaphor (TBM), for the awareness of Inclusion in Chemical Education (ICE), enriching the contributions of Johnstone and Mahaffy.

2 DIFFERENCE BETWEEN INTEGRATION AND INCLUSION

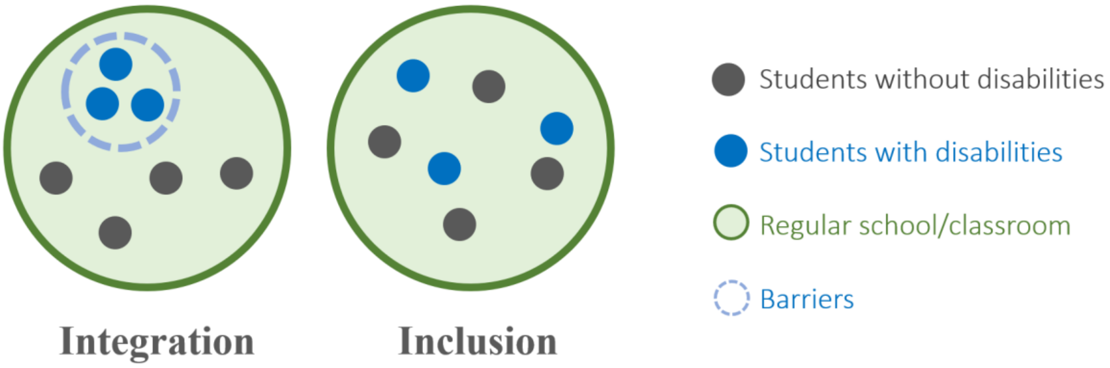
How can we differentiate integration from inclusion? Before answering this question, we need to understand what segregation and exclusion are. In short, exclusion refers to the process of leaving some people out of a group. Segregation refers to the process of setting someone apart from other people. Exclusion occurs when a student – with or without disabilities – does not have access to education at any level. For example, for long-time, deaf students were excluded from all schools because people believed that they could not learn with others. This reality began to change when special schools were built for students with disabilities. Exclusion gave place to segregation. In this scenario, students could access education, however "exclusion" remains, because special schools only cater to students with disabilities. Figure 1 illustrates the difference between exclusion and segregation.

Figure 1: Difference between exclusion and segregation.



Integration refers to the process of assimilating someone in a place. On the other hand, inclusion refers to the process of being included within a group rather than excluded from it. Integration occurs, for example, when a student with a disability can access a regular school for their studies. In Brazil, there is specific legislation about education which states that all students need to study in regular schools rather than special schools[19]. However, exist many barriers to accomplishing this. It is more important to ensure that all students can learn in an inclusive way, rather than simply opening the doors of schools to everyone. In this context, integration can give rise to inclusion. Figure 2 illustrates the difference between integration and inclusion.

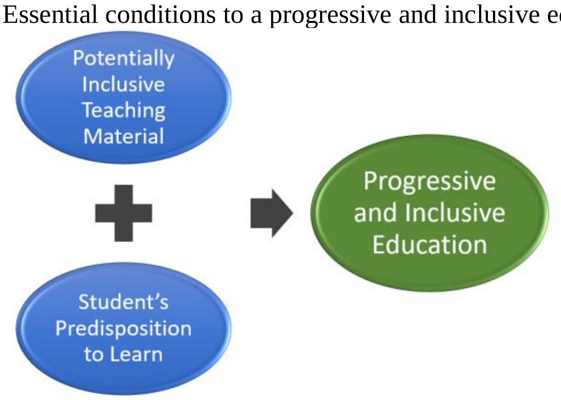
Figure 2: Difference between integration and inclusion.



It is critical that we can differentiate integration from inclusion, as a result that we can effectively implement inclusive education. Genuine inclusion occurs when all students are educated in regular classrooms in their local school alongside their same-age peers with adjustments to curriculum, instruction, assessment and the environment[20].

Inclusion is progressive and the teacher's role is to provide conditions to achieve it. Progressive means a gradual development, which involves proceeding step by step. According to David Ausubel, author of the Meaningful Learning Theory (MLT), teaching can only happen when learning occurs, and learning must be meaningful[21–24]. Inspired by Ausubel's studies, we propose two conditions to a progressive inclusion: i) potentially inclusive teaching material, and ii) student's predisposition to learn, as illustrated in Figure 3.

Figure 3: Essential conditions to a progressive and inclusive education.

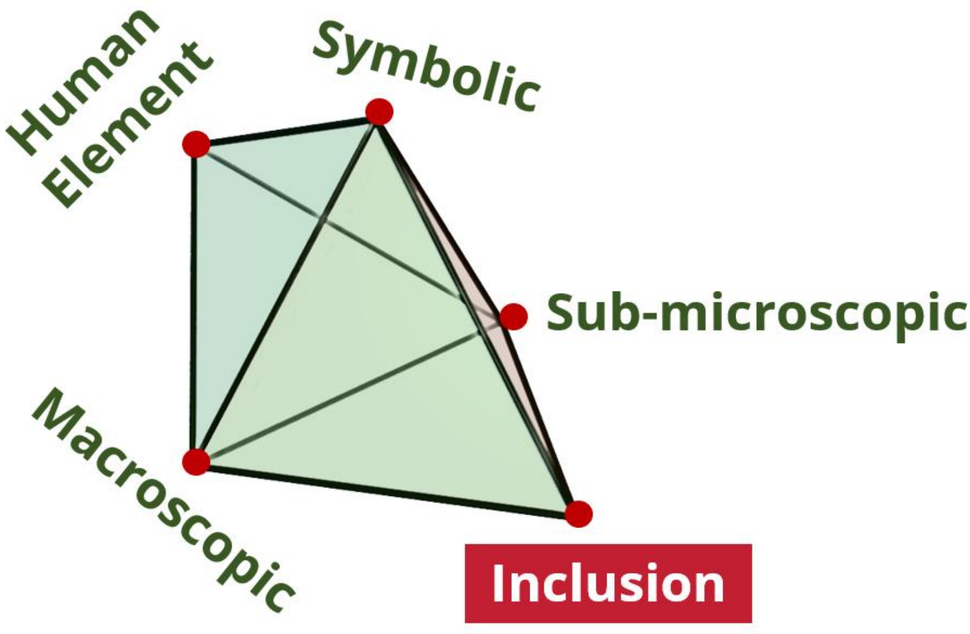


Based on the first condition - potentially inclusive teaching material - we believe that inclusion resides in people, not in things. In other words, there is no such a thing as an inclusive video or class, but instructional materials can be potentially inclusive. Thus, they must have adequate language and allow students to learn. Based on the second condition - student's predisposition to learn - it is interesting to observe that it is addressed to all students, guiding them in a frame of mind to be willing to learn.

3 WHAT IS THE TRIANGULAR BIPYRAMID METAPHOR (TBM)?

In this context, we proposed a new pictorial representation, the Triangular Bipyramid Metaphor (TBM), illustrated in Figure 4. In Geometry, a triangular bipyramid is a type of hexahedron, which has five vertices. Consequently, TBM shows that chemistry can be represented at five levels: symbolic (communicative representation), sub-microscopic (theoretical representation), macroscopic (phenomenological representation), human aspect (human context representation) and inclusion (accessible/inclusive representation), which are considered together as levels of chemical representations.

Figure 4: Triangular Bipyramid Metaphor (TBM), describing the five levels of instruction in chemical education as corners of a triangular bipyramid.



This new level of instruction, as the human aspect, includes the formal aspects of chemistry teaching (the chemistry triplet). If we understand that inclusion is more than integration, we have the choice to advance by helping our students see their potential. Thus, by making the education content more accessible to such students, they are able to understand the material and advance their understanding. TBM is about the power of building comprehensive, accessible and critical strategies to support everyone.

In terms of having diversity, by including people from different cultures and backgrounds (with very different life experiences), when everyone possesses the same knowledge, they are able to form their own understandings, which can lead them to derive their own unique conclusions and insights with can further scientific knowledge.

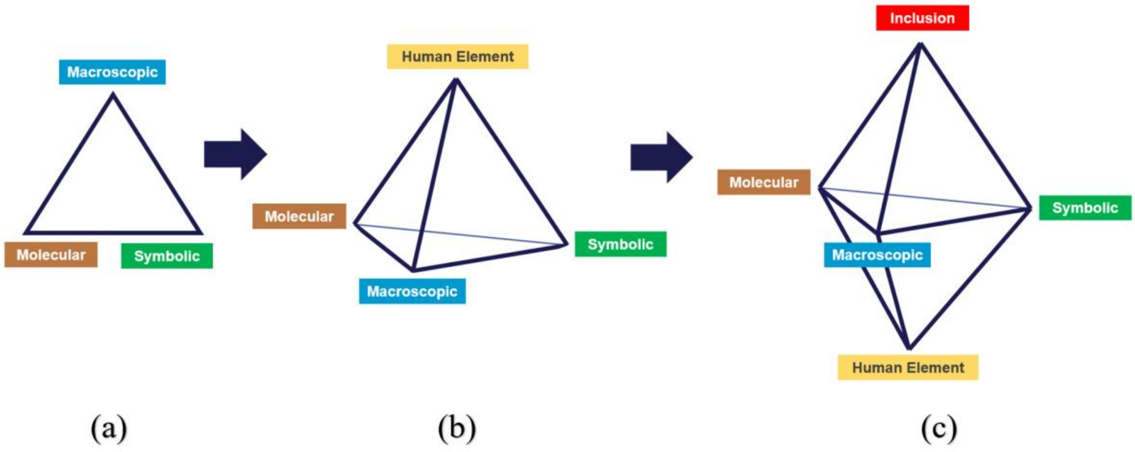
4 TBM AS A NEW SHAPE OF CHEMICAL EDUCATION

How could this new model be a powerful pedagogical framework for teachers, students and researchers? There are many ways to answer this question, however in the digital era, a practical idea for using TBM is to create educational videos on YouTube[25,26]. According to Smith[27], "social media provide a unique arena in which chemists can communicate directly with an international audience from a wide range of backgrounds" (SMITH, 2014, p. 1594).

In the case of a virtual class with both deaf and hearing students every corner of the TBM must be considered which include demonstration of experimental laboratory (the macroscopic level), representation of equations (the symbolic level), utilization of molecular animations (the sub-microscopic level), focus on cultural or socioeconomic factors (the human aspect), and incorporation of Sign Language (the inclusion level). A growth of research on inclusive strategies has been observed in the literature[28–50], however there is a gap in the use of illustrative models to guide students and teachers, which is where TBM comes into play.

As Mahaffy pointed out, "beyond inviting imaginative responses to the world, of course, it is our task as educators to work with and equip the world's students to build a better one" (MAHAFFY, 2004, p. 54). TBM is not a simple geometric figure to address changes in pedagogical frameworks. Rather, it is a purposeful responsibility to promote a sense of having empathy and inclusion, based on a meaningful learning. It is an evolution of the Johnstone's triangle and the Mahaffy's tetrahedron, as illustrated in Figure 5.

Figure 5: (a) Johnstone's triangle (b) Mahaffy's tetrahedron (c) Triangular Bipyramidal Chemistry Education: an emphasis on the inclusion.



5 FINAL CONSIDERATIONS AND PERSPECTIVES

The goal of this work was to propose the Triangular Bipyramid Metaphor (TBM), a new pictorial representation for the awareness of Inclusion in Chemical Education (ICE). This new metaphor is depicted as having a triangular bipyramidal shape with five levels of instruction: (1) symbolic or representational, (2) sub-microscopic or model, (3) macroscopic or phenomenological, (4) human aspect or context, and (5) inclusion. A growth of research on inclusive strategies has been observed in the literature[28,29,38–47,30,48–50,31–37]; however, there needs to be more illustrative models to guide students and teachers, which is where TBM comes into play.

We pondered the difference between integration and inclusion, and it was proposed two conditions to a progressive and inclusive education: i) potentially inclusive teaching material, and ii) student's predisposition to learn. These are important considerations, given that a common concern that arises when teachers discuss the inclusion of students in chemistry classes. As a new conceptual metaphor, the use of TBM will help create and develop novel solutions through interdisciplinary and comprehensive collaborations, supporting our work with students and the public.

Only a few students from underrepresented groups start their chemistry studies, and an even smaller number complete their studies and enter the workforce in the field of Chemistry. Triangular bipyramidal chemistry education can provoke us to find new ways for Diversity, Equity, and Inclusion. We need to solve our problems with a different way of thinking that we used to create them, providing novel resources for ICE. For perspective, TBM could also be applied to other fields of science, such as Biology and Physics, to make them more inclusive.

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