BIOMECHANICS IN PHYSICAL EDUCATION COURSES: A PEDAGOGICAL VIEW

(A Biomecânica nos cursos de Educação Física: um olhar pedagógico)

Rachel Saraiva Belmont [rachelsbelmont@gmail.com]
Salgado de Oliveira University. Graduate Program in Physical Activity Sciences.
Oswaldo Cruz Foundation, Graduate Program in Bioscience and Health Teaching
Laboratory of Environmental and Health Education
Av. Brasil 4365, Manguinhos. Lauro Travassos
Rio de Janeiro 21040-360, Brazil.
Evelyse dos Santos Lemos [evelyse@ioc.com.br]
Oswaldo Cruz Foundation, Graduate Program in Bioscience and Health Teaching
Laboratory of Environmental and Health Education
Av. Brasil 4365, Manguinhos. Lauro Travassos
Rio de Janeiro 21040-360, Brazil.

Abstract

When we think about the physical education professional performance and the basic knowledge that guides this work, it is easy to recognize the essential role of biomechanical concepts. Physical education professionals who did not learn the fundamentals of biomechanics, tend to have more difficulty applying knowledge in practical contexts. One of the possible causes for this problem is related to teaching and conceptual learning in undergraduate courses. Addressing this question, the aim of this paper is to discuss how the meaningful learning theory can inform teaching and learning biomechanics in undergraduate physical education courses. The text will focus on "what" to teach and "how" to teach the central concepts of biomechanics using the assumed theoretical framework. In this way, we hope to broaden the discussion about the educational process in order to foster meaningful learning of biomechanics in physical education courses.

Keywords: Higher Education. Meaningful Learning. Didactics.

Resumo

Quando pensamos na atuação do profissional de Educação Física e nos saberes básicos que orientam este fazer, é fácil reconhecer o papel central dos conceitos biomecânicos. Profissionais da área de Educação Física, que pouco aprenderam os fundamentos da Biomecânica, tendem a apresentar maior dificuldade na aplicação desse conhecimento nos contextos práticos. Uma das possíveis causas deste problema é o processo de ensino e de aprendizagem conceitual nos cursos de graduação. Partindo desta realidade, o objetivo deste ensaio é discutir como a Teoria da Aprendizagem Significativa pode subsidiar o processo de ensino e de aprendizagem da Biomecânica nos cursos de graduação em Educação Física. A reflexão se centra no "que" ensinar e em "como" ensinar os conceitos centrais da Biomecânica utilizando o referencial teórico assumido. Esperamos ampliar a discussão sobre o processo educativo voltado para o favorecimento da aprendizagem significativa da Biomecânica nos cursos de Educação Física.

Palavras-chave: Ensino Superior. Aprendizagem Significativa. Didática.

Introduction[1]

Biomechanics is a core discipline in most physical education (PE) degree courses because it is regarded as fundamental in the exercise of this profession. Adrian and Cooper (1995) define Biomechanics as the "branch of science concerned with understanding the interrelationships of structure and function of living beings with respect to the kinematics and kinetics of motion" (p. 4). This field involves the description and the study of human movement causes (Knudson, 2007). Although this body of knowledge helps guide teachers in deciding the most adequate interventions for the education process, researches about teaching and mainly learning of biomechanics are still incipient. Knudson (2010) reviewed articles published in proceedings of the North American conferences and in journals about teaching biomechanics and concluded that, until that year, there were few studies focusing on learning biomechanical concepts and teaching strategies.

Despite the consensus about the importance of this subject in PE teachers training in undergraduate level, its concepts are still little applied by teachers in their professional practices. Although little used, most PE professionals believe that Biomechanics should be kept in the undergraduate curriculum (Corrêa, 2004). According to Ladeira et al. (2011) high-performance coaches are more concerned with biomechanical concepts than school PE teachers.

Many factors can limit the appropriation of biomechanical content by PE professionals, such as: (i) difficulty in understanding the specialized language and accessing scientific texts (Sanders & Sanders, 2001); (ii) the fact that the knowledge produced in this field is rarely centered around the pedagogical questions that teachers will actually use (Batista, 2001); (iii) the fact that teaching methods used in introductory courses are not foster the concepts understanding and its application (Corrêa & Freire, 2004); (iv) in the Brazilian context, the limitations of National Curriculum Parameters (reference for elementary and high school teachers) that associates biomechanics mainly with posture correction and competitive sports, showing little relation to schools realities (Freitas & Lobo da Costa, 2000).

We will not focus on the causes of the biomechanics little application in PE professional daily life. However, it is important to emphasize that the problem is also centered on the teaching and conceptual learning process developed in undergraduate courses. PE professionals who have not learned the fundamentals of biomechanics with meaning will have greater difficulty in using this knowledge in practical contexts. Belmont, Batista, and Lemos (2011) identified that introductory biomechanics students had difficulties in using the biomechanical knowledge when they had to solve problems that required relationships between two or more concepts. In addition, most of these students did not see themselves as being responsible for their own learning since they had a greater disposition to memorize definitions than meaningful learning (Belmont & Lemos, 2012).

Based on the understanding that learning must be meaningful for the successful development of PE professionals, meaningful learning theory (Ausubel, Novak & Hanesian, 1978, Ausubel, 2000, Gowin, 1981, Novak, 2010) is used as the theoretical framework in this essay. The aim of this essay is to discuss how the meaningful learning theory can inform teaching and learning biomechanics in undergraduate PE courses. The discussion will focus on "what" to teach and "how" to teach the central concepts of Biomechanics using the theoretical framework. We hope to collaborate with knowledge about the teaching process concerned with the meaningful learning of Biomechanics and consequently about training in undergraduate PE.

[1] Essay adapted from the original in Portuguese "Teaching biomechanics in physical education courses: reflections with meaningful learning theory", published in the International Journal on Active Learning, 2016. Doi: http://dx.doi.org/10.15202/2526-2254.2016v1n1p99.

Key teaching ideas according to Meaningful Learning Theory

Meaningful learning is the central concept of the theory proposed by Ausubel, Novak, and Hanesian (1978). For learning to be meaningful, the learner must relate new information to relevant ideas in the cognitive structure in a non-random (non-arbitrary) and substantive (non-literal) way. Meaningful learning, therefore, requires active interaction and integration between new concepts and the student's prior knowledge. In this assimilation process, both the new information and the prior structure end up being modified.

Ausubel (2000) also draws attention to rote learning, which is often prioritized in educational settings today. In this case, unlike meaningful learning, the new information interacts with the learner's cognitive structure in a random and literal way. In other words, in the memorization process, the new information is scarcely related or unrelated to prior specific knowledge, resulting in a limited or non-existent acquisition of new meanings. Ausubel (2000) explains that ideas learned by memorization can only be applied to similar situations to the ones that they were originally memorized. In contrast, solving problems in new situations demands organized and consolidated knowledge which is consistent with what occurs in the meaningful learning process.

For meaningful learning to occur, teaching materials must also be potentially meaningful, that is, relatable to the learners' cognitive structure. Meanwhile, the learner must also have the disposition to learn in a meaningful way, acting intentionally to establish conceptual links both substantively and non-arbitrarily.

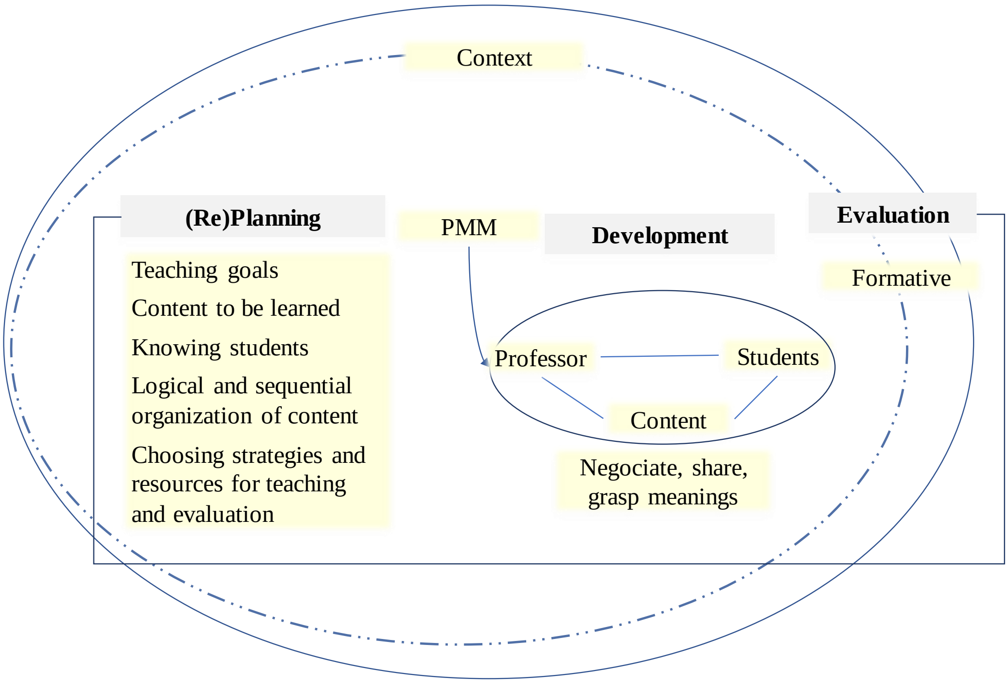

Figure 1. Variables involved in learning processes according to meaningful learning theory. Each stage interacts with all others during the education process. The final evaluation which includes the five elements of education, is essential for reformulate teaching play. PMM -potentially meaningful material

It is down to educators to create situations that enable learners to engage in meaningful learning. According to Novak (2010), the educational process involves not only cognition, but also contextual, affective, and procedural factors. The teacher and learner interact with knowledge in a process that is constantly under evaluation and takes place in a specific context. Social interaction is therefore fundamental for the acquisition of new knowledge. Gowin (1981) postulates that teachers and learners are jointly responsible for any learning process. The meanings of the teaching materials should be negotiated and shared between teacher and learner in a dialogical process with the aim of enabling meaningful learning. Figure 1 sums up the dynamics that take place in the different stages of learning informed by meaningful learning theory. It is no simple task to obtain meaningful learning evidences. Ausubel, Novak, and Hanesian (1978) recommend preparing written or oral questions, tests, and activities in such a way that the learners are unable to resolve them merely by reproducing what they have memorized. In other words, the questions and/or problems should be formulated in new language and present situations other than the ones discussed in the classroom.

Teaching is a complex event that should be understood and practiced to foster meaningful learning (Lemos, 2005). The teaching process should help the learner perceive conceptual relationships and lead them to understand the logic of the knowledge building process, helping them develop autonomy to learn. Seen from this perspective, teaching requires paying attention to learners' emotional and cognitive faculties, their micro and macro-social context, and the nature of the knowledge to be taught. As we will detail below, it is not the quantity of content that matters, but getting across the core ideas so that the learner can build up a knowledge framework that allows them to continue learning.

Content of introductory biomechanics courses

According to the literature, concerns about what should be taught in introductory biomechanics in undergraduate PE degree are not recent, although the discussion has gained ground in recent years. Alongside the content, another recurring feature of this debate is what method for analyzing movement should be prioritized at the undergraduate level, which, depending on the focus, may be qualitative or quantitative.

Some years ago, Davis (1984) discusses the "pedagogical dilemma" in the teaching of biomechanics at undergraduate level. In the "biomaximechanics" approach, there is a focus on physics and mathematics, preparing students for advanced studies, graduate level. The other approach, to which he addresses more attention in his article, is "biominimechanics," which consists of teaching the minimum essential of theories and emphasize practical problems. Davis did not mention what content should be covered but suggests that the teaching materials used—which until then had been very specialized and mathematically oriented—should be simplified so that students develop the understanding of the area and skills to conduct qualitative analyzes. In other words, he proposes that emphasis be placed on solving practical problems, since the "students then see the relevance of the theory and are perhaps more motivated to understand the concept" (Davis, 1984, p. 120). Finally, he suggests that teaching biomechanics should focus on simple analysis techniques, like recording and photography for qualitative analysis of movement that is likely more used by teachers in their professional contexts.

Strohmeyer (2004) and Corrêa and Freire (2004) also draw attention to the importance of content application and propose some essential concepts of biomechanics for PE teacher practices (Table 1). After explaining the concepts, the authors give examples of their applications drawn from the everyday teaching of PE. Although Strohmeyer (2004) does not mention qualitative or quantitative analyses as methods to be used on introductory courses, Corrêa and Freire (2004) suggest giving priority to qualitative analyses in the teaching, going on to explain that concepts studied should be presented with clear applications, showing learners how they could be applied in their everyday practice, but without failing to introduce basic equations. Vilela Junior (1999) believes that the teaching biomechanics should not give up the "guiding principles of this field of knowledge, which are constructed by applying specific methodologies to the study of human movement in the light of Newtonian mechanics" (p. 49). For him, it is not possible to give up teaching physics and mathematics under the argument that students have difficulties in assimilating these contents.

According to Vilas-Boas (2001), the curriculum and teaching methods should be designed to meet the goals of the scientific discipline, the area in which the students will work professionally, and “enhancing students' competencies for observation, analysis and subjective evaluation of techniques" (p. 52). The guidance document that provides guidelines for undergraduate biomechanics in the United States (SHAPE, 2018), proposes that by the end of the course, students should be able to demonstrate basic skills to observe, analyze and evaluate human movements in sports, clinical, educational and work environments. In order to put this into practice, the document advises that the courses should work within the continuum between qualitative and quantitative analysis, integrating anatomy and mechanics knowledge. (Table 1).

Knudson (2003) presents a historical overview of biomechanics research and teaching, indicating an unbalance between biology and mechanics contents, with the emphasis in the latter and quantitative analyses of human movement. He holds that biomechanics courses should have a careful balance between the biological and mechanical fundamentals, with the application of these to real-world human movement. Although many faculties are in favor of using a quantitative approach, courses could give students access to both methods of analysis. Knudson (2003) also argues that "if the instructor must emphasize one over the other, the predominant emphasis should be the qualitative understanding and application of biomechanical concepts" (p. 128).

Table 1. Essential principles and concepts for introductory biomechanics courses. The presentation of ideas does not correspond to the possible correspondences between concepts

Hudson (1995)	Vilela Junior (1999)	Knudson (2003, 2007)	SHAPE (2018)	Strohmeyer (2004)	Corrêa and Freire (2004)
Range of motion *Speed of motion* *Number of segments* *Nature of segments* *Balance* *Coordination* *Compactness* *Extension at release* *Path of projection* *Spin*	*Static: forces in equilibrium acting on the body* Contact forces, gravity, tension, balance, principles of hydrostatics. Resulting forces *Kinematics: the human body in motion* Uniform motion, uniformly variable motion, variable motion *Dynamics: the human body in unbalance situations* Newton’s laws. Work and energy Hydrodynamics principles *Introduction to biomechanical tools* Laboratory experiences.	*Force–Motion* *Force–Time* *Balance* *Inertia* *Range of motion* *Coordination continuum* *Segmental interaction* *Optimal projection* *Spin*	*Anatomical bases* Joint structure and function Muscle mechanics Neuromuscular function *Mechanics bases* Basic considerations: system’s movement, vector operations. Movement kinematics Movement kinetics Laboratory experiences.	*Force* Tension Gravity Equilibrium Force Absorption Friction	*Concept of Linear and angular velocity and the relationship between them* *Newton’s first Law* *Newton’s second law: linear and angular motion* *Newton’s third law*

Focusing on professionals who work with movement, Hudson (1995) puts forward ten core biomechanical concepts that should be learnt (Table 1). She draws an analogy between these concepts and musical elements that can be manipulated. Thus, depending on the motor skill and its goal, biomechanical concepts can be manipulated in such a way as to improve the movement.

Likewise, Knudson (2003, 2007) proposes nine principles (Table 1) to improve movement and reduce the risk of injuries. He argues in favor of qualitative biomechanics for undergraduate courses and suggests that the principles can be applied in qualitative analyses. Although some of the principles put forward by Hudson (1995) and Knudson (2007) are similar, Hudson places more attention on kinematics, while Knudson focuses more on kinetics. Both are in fact equally important for the acquisition of knowledge in the area, but in introductory biomechanics courses, it seems to us that teaching the causes before the description of movements could help students understand the logic of knowledge structure.

Ausubel, Novak, and Hanesian (1978) suggest that the central ideas of content should be taught before the more specific ones, always bearing in mind students' prior knowledge. These core ideas are the fundamental ideas or concepts underpinning other more specific concepts. Therefore, the relationship between force and movement is fundamental to all the other relationships inherent to mechanics. Also, by their very nature, principles express conceptual relationships that are crucial for meaningful learning. According to Novak and Gowin (1984), principles are "conceptual rules governing the linking of patterns in events; propositional in form. […]" (p. 56).

Because Knudson (2003, 2007) presents biomechanical principles, his proposal may be more compatible with meaningful learning theory, provided that it is planned and developed according to it. Belmont, Knudson, and Lemos (2014) present an example of teaching proposal based on this theory which integrates Knudson's (2007) biomechanical principles with those of the qualitative diagnosis of movement (Knudson, 2013) focusing on continuing teacher education.

Some of the pedagogical issues faced in biomechanics courses in Brazil are similar to those identified by foreign authors. Although four foreign authors (Hudson, 1995, Knudson, 2003, 2007, SHAPE, 2018, Strohmeyer, 2004) and two Brazilian (Corrêa & Freire, 2004, Vilela Junior, 1999) have suggested contents to introductory biomechanics, there is a consensus, with subtle differences, on the essential content to be taught to undergraduate students (Table 1). Alongside the biomechanical concepts, most of the authors also recommend prioritizing qualitative over quantitative analysis.

In this brief presentation on the issues that involve the teaching of Biomechanics, it is possible to verify that the vision about teaching and learning has been changing gradually. Despite the clear concern with regarding educational setting, the authors did not provide a deeper discussion about pedagogical content knowledge of biomechanics. It is essential that the debate about teaching and learning biomechanics does not center only in the specific content, but it also focuses on how the concepts are organized, presented and evaluated.

How to teach the core biomechanical concepts at the undergraduate level

Just as mastery of the specific biomechanical knowledge, the pedagogical content knowledge is essential for the planning, development, and evaluation teaching. According to Shulman (1986), pedagogical content knowledge does not just help teachers find the best way to teach, but it also helps them to understand why some ideas will be more easily learned than others. In other words, for the teaching of biomechanics has the potential to foster the comprehension and use of these concepts in professional practice, teachers must consider, in addition to the specific content, the variables that will concomitantly influence the educational process, which, according to

Novak (2010), are: student, content, teacher, context, and evaluation (Figure 1). In the constructivist paradigm, understanding how students learn is key to planning teaching proposals committed to meaningful learning.

Porto et al. (2013) investigated the training of biomechanics professors who teach in undergraduate PE courses in Rio de Janeiro state, Brazil. The authors argue that the fact that many professors are physiotherapists may not be positive for the quality of teaching because there are specificities from PE field that may not be considered by them. In addition to this question and considering the Shulman's (1986) ideas, another problem associated with the physiotherapist professor is the lack of pedagogical training to teaching. Although this is an important matter, we will not focus on it.

According to the theoretical framework adopted, there is no one "right" way to teaching biomechanics, but there are some general ideas that are worth considering. In planning, it is fundamental that teachers determine the content to be learned by the student. Considering the number of hours available, it is crucial to define the relevant and central content ideas. According to Ausubel, Novak, and Hanesian (1978, p. iv), "the most important relevant single factor influencing learning is what the learner already knows". That is why professors must know the students' prior knowledge. This verification can be done by diagnostic tests or even by asking verbal questions to the students during classes. The anatomy course is usually prerequisite to introductory biomechanics. It is expected that PE students have learned the core concepts after finished this course. However, the inadequacy of this knowledge tends to be a recurring problem on biomechanics courses. When the students' prior knowledge of musculoskeletal anatomy is insufficient, fragmented, or missing, this can be a barrier to meaningful learning biomechanics. (Belmont et al., 2016). They identified that the students' lack of previous knowledge about anatomy, physiology, mathematics, and basic physics poses difficulties in teaching biomechanics (Garceau, Ebben & Knudson, 2012).

This initial diagnosis is essential for designing potentially meaningful teaching materials. Furthermore, if the educational setting and its cultural, emotional, and physical dimensions (the school environment and materials) are considered when the content, strategies, and instructional resources are selected, this helps the students perceive and establish meaningful conceptual relationships. Instructional resources and teaching strategies that consider not just the specific content, but problems like that students will find in their professional lives, will motivate them to participate actively in their own learning process.

In teaching development phase, professors should create situations where the learners will have the chance to reflect on, negotiate, share, and grasp meanings from the instructional materials. Active learning strategies developed in line with the constructivist paradigm can help diminish the importance students place on rote learning. For instance, in inquiry-based teaching, students are encouraged to formulate hypotheses about the phenomena studied, negotiating them with their classmates and then with the teacher (Carvalho, 2011). In this case, the capacity to argue is essential in the knowledge-building process, because it requires the student to "assess the statements based on evidence, recognize that the scientific statements and conclusions must be justified, that is, supported by proof" (Jimenez-Aleixandre, 2010, p. 23). Finally, the students confirm or refute their hypotheses by conducting an experiment or activity. Belmont, Máximo-Pereira, and Lemos (2016) applied an interdisciplinary inquiry-based activity combining physics and physical education concepts to high school. Although this activity was not planned for students at the undergraduate level, it could be adapted for them because the problem studied —whether there is any variation in the soccer ball velocity when it is kicked from a stationary position and from a run-up— is relevant biomechanical content.

Another educational strategy that involves an active learning approach is the flipped classroom, the main aim of which is to encourage greater student participation during classes. Students study the material and/or watch videos on the subjects out of class so that the class time can be spent on practical activities and/or problem-solving (Sams & Bergmann, 2013). According to Breloff (2015), the application of the flipped classroom in a biomechanics course allowed for greater interaction among students, a better understanding of content, and reduce lectures in classes. Knudson (2016) points out the positive points of active learning strategies in teaching biomechanics, explaining that they can foster better conceptual learning than traditional teaching strategies. The author also proposes that the implementation of these strategies should be progressive because many students will be resistant to such a change, choosing to memorize the content.

It is important to emphasize that instructional resources and strategies used without planning will not assure learning, even if they are based on active learning methods. By taking part in active learning activities, students are expected to think with and about biomechanical knowledge in order to recognize and explain the phenomena, as well as solving problems inherent to human movement. Thus, the teaching strategies should be supported by theoretical-pedagogical frameworks consistent with the constructivist paradigm and meaningful learning. In a review study on the flipped classroom approach, O'Flaherty and Phillips (2015) draw attention to a lack of pedagogical approach guiding the design, implement, and evaluate the effectiveness of the strategy.

In this way, the appropriate strategy for teaching biomechanics is the one that considers students' prior knowledge, the knowledge structure to be learned, the contextual factors, and also promotes social interactions, in which students have the opportunity to formulate hypotheses, negotiate and share the meanings of concepts with professor and classmates. (Figure 1). In other words, professors should provide learning environments where students take part actively in building their own knowledge and become autonomous learners.

Irrespective of teaching strategy or active learning method used, the evaluation must be present throughout the educational process. From the meaningful learning perspective, evaluate should be formative, but may also be summative. For instance, when students negotiate meanings, they will express their thoughts in words, providing important information for the professor, who can obtain indicators of how they are thinking. For the students, this interaction offers immediate feedback, enabling them to ascertain whether the meanings of the concepts they have grasped correspond to the meanings the professor wanted to teach them. Mediated by the evaluation of both, student and teacher, the negotiation of meanings tend to culminate in a share of these meanings between those involved (Gowin, 1981).

According to Ausubel, Novak, and Hanesian (1978), in the evaluation process, students should present meaningful learning evidence: they must be capable of using knowledge in new situations. In the tests and activities proposed, students must explain with arguments the phenomena clearly and autonomously in their own words. It is fundamental that professors elaborate problems in a way that students are not able to solve them using memorized content. Other meaningful learning evidence is observed when students solve different problems that involve the same concepts successfully. As Vergnaud (2009) explains, the greater variety of problem situations experienced by students, the more relationships between concepts will be established by them. Even if problems demand the same concepts, the routes taken to solve them will not always be the same. Thus, the more consolidated the knowledge, the more capable students will be of applying it to unfamiliar situations. Applying a continuing education proposal for PE teachers, Belmont (2015) investigated the progress of meaningful learning, assessing the same conceptual relationships that learners expressed in different problem situations. The results indicated that knowledge acquisition took place in a non-linear way and the students advance in conceptual learning, showing improvement in the use of knowledge to solve problems in the posttest.

In the evaluation phase, teacher, content, student, context as well as strategies and measurement tools, used to verify students' learning, should be evaluated constantly to improve the educational process (Figure 1).

Final considerations

Although biomechanics is one of the core disciplines of PE courses, its application in professional practices is still incipient. One of the assumptions of this essay is that the limited use of biomechanical concepts is also related to teaching practices. Some authors proposed essential contents of biomechanics to training undergraduate PE professionals. The discussion about the specific content to be taught is essential, however, the focus should equally be on the pedagogical content knowledge. Without this, it is harder for professors to comprehend the students' learning difficulties and facilities, and thus to propose alternatives that help them to think with and about the knowledge to apply it. Therefore, it is important to have a theoretical-pedagogical framework to support the actions involved in the teaching phases. Understanding how students learn and the role of the five elements of education is the best way to foster meaningful learning and encourage students to develop autonomy to learn.

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