Interactive Model Tool about Center of Mass during COVID-19 Pandemic: A New Learning Path in STEM for K-12 Education

Otacilio Antunes Santana
Departamento de Biofisica e Radiobiologia
Universidade Federal de Pernambuco
Recife, Brazil
otacilio.santana@ufpe.br

Garuda das Braga
Programa de Pós-Graduação em Rede Nacional para Ensino das Ciências Ambientais
Universidade Federal de Pernambuco
Recife, Brazil
garuda_fisica@yahoo.com.br

Jose Otavio de Sa Braga
Programa de Pós-Graduação em Rede Nacional para Ensino das Ciências Ambientais
Universidade Federal de Pernambuco
Recife, Brazil
hari_fisica@yahoo.com.br

Helotonio Carvalho
Departamento de Biofisica e Radiobiologia
Universidade Federal de Pernambuco
Recife, Brazil
helotonio.carvalho@ufpe.br

2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) | 978-1-7281-6942-2/20/$31.00 ©2020 IEEE | DOI: 10.1109/TALE48869.2020.9368486

***Abstract*—The pandemic caused by Sars-CoV-2 resulted in a period of physical distance and school closures. This motivated us to elaborate on some physical and psychological harm reduction plan for the students. A challenge was proposed to K-12 students from Public Schools of the Recife City: physical exercises in which the students could learn playfully and experientially a concept of Natural Sciences. The chosen concept was the "center of mass" because it is a biometric, dynamic, and contextual variable linked to body movement, which could be experienced in the quarantine period. The objectives of this work were: (i) to propose a challenge through the physical exercise to K-12 students (jumping jacks), which implies the study of "center of mass" (COM) concept, (ii) to quantify the dependent variable COM and to relate with independent variables (e.g. body mass index), (iii) to build a learning object "Interactive Model" from the data obtained, (iv) to evaluate the didactic process. The objectives proposed were successfully implemented. The Interactive Model: "Change your Center of Mass!" was built and evaluated by teachers of Public Schools (Brazil), who highlighted its potential (impact, complexity, applicability, innovation) suggesting the model to the educational system.**

Keywords—playfulness, national common curricular base, biophysics, sustainable development goals, praxis

I. Introduction

On March 11, 2020, the World Health Organization declared a State of World Emergency due to the COVID-19 Pandemic [1]. Before that, on February 25, 2020, in Pernambuco State, Brazil, the first COVID-19 suspect with symptoms was registered on a "Silver Shadow" Transatlantic Ship, anchored at the Pernambuco Passenger Maritime Terminal (Porto Recife). On March 17, 2020, there was the first protocol confirmation of a person contaminated with Sars-Cov-2, the date on which the Governor of the State of Pernambuco decreed the Physical Distance Measures - Quarantine [2], following Federal Law [3].

As of March 18, 2020, the closure of schools became official, but before that, educational establishments already reported a reduction in the attendance of some students and education professionals. This motivated us to elaborate on some physical and psychological damage reduction plan that the pandemic closure brings [4], [5]. This plan was a challenge to K-12 students from Public Schools: physical exercises in which the students could learn in a playful and experiential way a concept of Natural Sciences [6]. This challenge focused on building cognitive, socio-emotional, and behavioral skills, and on quality of life through the care of the physical health of educational actors [7].

The chosen concept was the "center of mass" because it is a biometric, dynamic, and contextual variable linked to body movement - kinesiology [8], [9], where students could be experienced in the quarantine period ('lockdown') through physical exercises. Also, there is a significant probabilistic relationship between the more a child is physically active (spontaneous and induced sports practices), the more the child's ability to learn and solve problems (within the zone of proximal development) [10], [11].

An Interactive Model ("Change your Center of Mass!") was built based on a mathematical model with the center of mass as a dependent variable and independent variables: body mass index and vertical jump, in which students and teachers could insert data, and qualify as your center of mass is: from regular (not very active physically) to excellent (in activity with high performance). And this interaction with the Model could be a motivating factor for the student to remain active during and after the pandemic.

The center of mass is a hypothetical point where the whole mass converges as if all external forces were being applied at that point. The center of mass can coincide with the center of gravity when a human body is under the influence of a uniform gravitational field [8], [12], [13]. This biophysical variable is important because it is related to the student's biomechanics and biometrics, his body volume has a direct and proportional relationship with his movement, it can be quantified (e.g. body mass index on running speed) and qualified: the perceptual effort used to get out of inertia (e.g. laziness) [14].

Jumping jacks is a physical exercise in which you can study and analyze the center of mass about its induced variation because it is a vertical movement in which, over time, we can verify a variation in the position of the center of mass in student (or athlete), if students are actives and change their independent variables: BMI and height of vertical jump [15].

In this period when students are at the Concrete operational stage (7 to 12 years old), they develop three skills [16]: (i) to establish relationships between different points of view and integrate them in a way logical and coherent; (ii) to internalize the actions, the student begins to perform operations mentally and not just through physical actions typical of sensory-motor intelligence; and (iii) to construct the reversibility, which is the ability to think simultaneously the initial and the final state of some transformation carried out on objects, subjects, and the environment.

As in another Piagetian stage, the construction of a systematic and regular 'habitus' is fundamental for the perception of variation (Δ), and the concrete recognition of change. The construction of a playful challenge is the potential to start the migration of concrete knowledge to hypothetical-deductive thinking (Formal operational stage) [17].

The 'Interactive Models' are those in which the user (student) can modify the independent variables and automatically observe the reflection of this change in the dependent variable [18]. With this, the student can change scenarios and situations on a deterministic (concrete) and probabilistic (formal) scale [19]. These interactive models take advantage of playfulness to present the real on a micro or macro scale (simulators) or to present the ideal with real data [20]. They are excellent, in addition to playfulness, to challenge the variation of 'habitus' in an educational environment (leaving the comfort zone).

In the literature, for the target audience in question and for the intentionality in the educational system, several interactive models were built to think about the concept of center of mass for: Sport Science [21], Modeling [22], [23], Instructional Design [24], [25], [26], [27], [28] and, Didactics [29], [30], [31]. STEM is an education policy and curriculum choices in schools to improve competitiveness in science and technology development [14], [23].

The objective of this work was to build a STEM tool as an Interactive Model on the biophysical concept of "Center of Mass" in which educational actors could, in a contextual way, build knowledge in a theoretical and practical way at the time of the social distance measures used to contain the virus SARS-CoV-2. The specific objectives were: (i) to propose a challenge through the physical exercise to elementary school students, which implies the study of the physical concept of "Center of Mass"; (ii) to quantify the dependent variable (Center of Mass) and related independent variables throughout the challenge period, and model these variables mathematically; (iii) to build an "Interactive Model" learning object from the data obtained; and, (iv) to evaluate the didactic process on criteria of technical and technological production.

II. Methods

The sample group analyzed was formed by students from the Middle School (K-12 education), 5th Grade (Brazilian System), who are nine to ten years old, from Public Schools at the Recife City, Brazil. The criteria for the participation of these students were: (i) voluntary acceptance of students and parents or guardians; (ii) to have a conventional measuring tape, scale and camera (e.g. cell phone, computer, ...) at home; and (iii) to perform the daily challenge of running jumping jacks in their homes (1,000 repetitions per day) over 120 days of quarantine in the COVID-19 Pandemic. On the 120 days, 16 days of rest (one per week) were allowed for those who wished. A person need to burn around 500 Kcal per activity (about 1,000 repetitions per day) for a significant change in body mass index in the medium term (e.g. three months). [32]

The direct and active participation of parents or guardians was essential for the supervision and validation of the data collected. They were contacted in the "Movimenta Recife" and "Academia Recife" projects, projects to encourage the practice of physical exercises as an integrating factor to the quality of life [33].

Every day, each student measured their: (i) body mass index (BMI = mass · height^{-2} = kg · m^{-2}, [34]), and (ii) height of the vertical jump (cm) = distance from the foot to the surface at the moment zero speed of the body in a vertical jump (Fig. 1); and filmed it 360° at rest and running jumping jacks (videos ⩾ 25 fps).

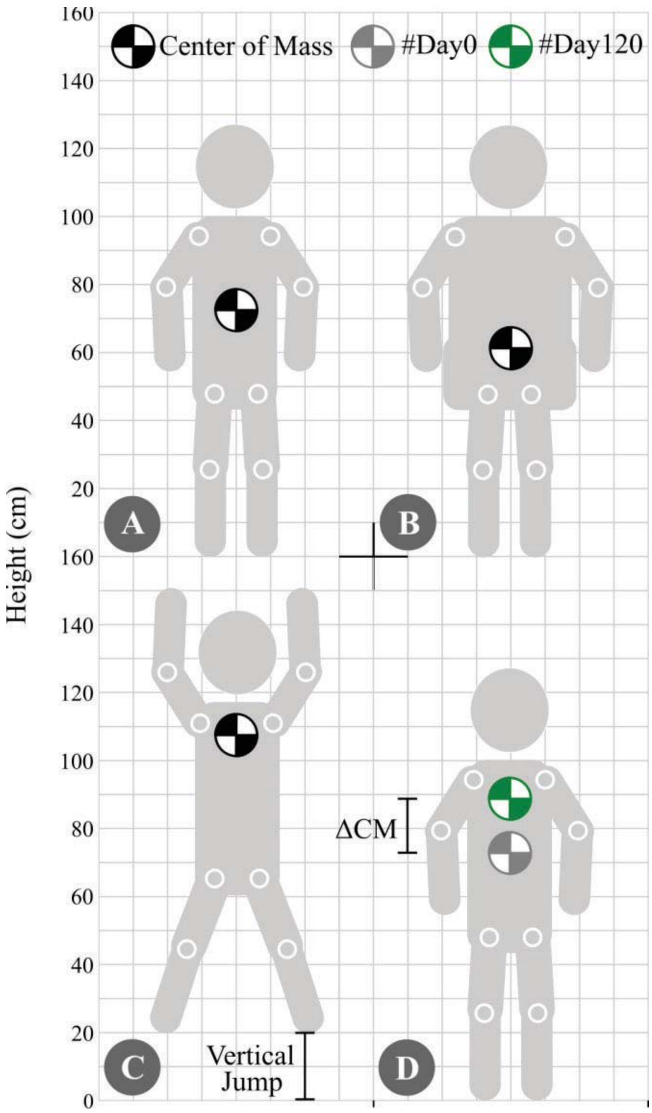

Fig. 1. Center of Mass variation (ΔCM) and vertical jump measures.

From the videos, the center of body mass of each student was estimated by the optimized models of training to identify patterns in PoseNet and DefNet videos [35], [36] using the database that defined the concept of center of mass for the type of targeting sample group [8], [12], [13], (Fig. 2).

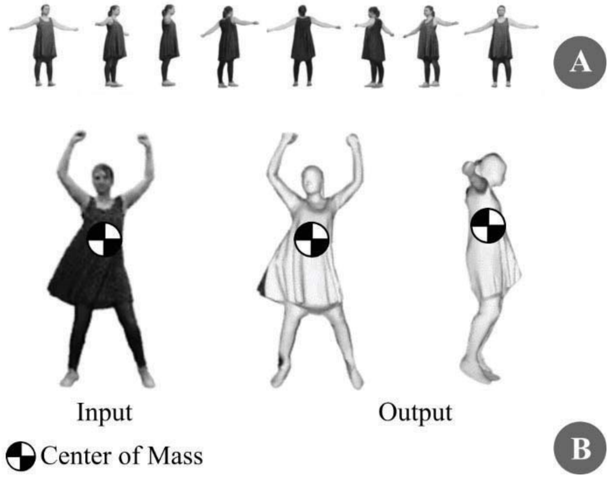

Fig. 2. (A) Frames of recorded video, and (B) Output of the Center of Mass estimation from the 3D body structure (Adapted [35]).

Statistical comparison between the periods #Day0 and #Day120 of each variable was performed using the parametric test T paired (95% confidence). Pearson's correlation (ρ) was performed among the independent variables to calculate the degree of proportionality between them [37]. The Normal Distribution requirement for parametric statistical was calculated from the D'agostino Distribution Test [38]. Statistical calculations were performed using the BioEstat 5.3 program [39].

As the basis of the Interactive Model to be created, a multiple linear mathematical model [37] was used to generate an automatic estimation equation for ΔCM. The student and teacher could observe interactively, over the days of execution of the exercises, the evolution or involution of this biometric variable [20]. As a dependent variable (ΔCM) and as independent variables (BMI and height of vertical jump) (1):

$$\Delta CM = \beta_0 + \beta_1 \cdot BMI + \beta_2 \cdot \text{Vertical Jump} + \varepsilon \quad (1)$$

Where, β = regression coefficient and ε = residual regression error. Residual error was normalized for the child's natural growth and for the calculation of BMI over time, according to the World Health Organization - WHO human growth curve [40]. The parameters and coefficients of the multiple linear mathematical model were calculated in the BioEstat 5.3 program [39]. Multicollinearity between variables was calculated [41].

The result of ΔCM could be qualified regarding the student's activity and the biometric consequence of this activity on a scale of four categories: excellent ($16 \leq BMI \geq 18$ and $24 \leq$ vertical jump ≥ 35), very good ($18 \leq BMI \geq 20$ and $16 \leq$ vertical jump ≥ 24), good ($20 \leq BMI \geq 22$ and $10 \leq$ vertical jump ≥ 16) and regular ($22 \leq BMI \geq 24$ and $8 \leq$ vertical jump ≥ 10), according to [40] and [32]. For didactic purposes, the term "regular" has been replaced by a motivational term: "Let´s go!" [42].

From the calculated previous equation, the Interactive Model was built in the Visual Basic for Applications language in the Microsoft Excel spreadsheet editor [43], due to the ease and popularity of handling (input and output).

Diagnostic evaluation was carried out before #Day0 to observe the collective knowledge of the concept of "Center of Mass", asking students: What is the word that comes up when you hear about "Center of Mass"? In the end, after #Day120, this same question was asked to assess the change in perception about the concept to be taught [44]. The answers were systematized in word clouds [45].

The teachers of the students who participated in the challenge validated the Interactive Model according to the technical production criteria of the Coordination for the Improvement of Higher Education Personnel (CAPES) [46], on a Likert scale [47] (from 0 = did not meet the criterion, 10 = completely met the criterion). The criteria are: (i) Impact (if the evaluation of this criterion is related to the changes that will result from the use of this Technical and Technological product in the environment in which it is inserted); (ii) Applicability (reference is made to the ease with which technical / technological production can be employed to achieve its specific objectives for which it was developed); (iii) Innovation (innovation is defined here as the rupture with the paradigms and everyday methods for the development of more efficient and effective products and techniques in professional practice with social implications); and, (iv) Complexity (Complexity can be understood as a property associated with the diversity of actors, relationships and knowledge necessary for the elaboration and development of technical / technological products).

As a complement to the evaluation by these five criteria, teachers were asked in an open survey: What are potentials and limitations of the Interactive Model for educational context?

At the end of the 120 days, a virtual meeting was held with everyone for the discussion and theoretical consolidation of the "Center of Mass" concept between students and teachers. This project was carried out from March 23 to July 20, 2020.

III. Results and Discussion

Of the 250 invited students, 117 students participated and completed the challenge, resulting in the collective average in a reduction of the body mass index (BMI), an increase in the vertical jump and an increase in the variation of the Center of Mass, from #Day0 to # Day120, all significantly ($p < 0.001$, Fig. 3). BMI data (kg m-2) were within the range $\{x \mid 23 \leq x \leq 16\}$ established by WHO [40] and vertical jump (cm) $\{x \mid 8 \leq x \leq 40\}$ as estimated by [32], for the age of the established sample group.

Over time, the curves of the independent variables BMI and vertical jump were non-linear (Fig. 3), however between the two there was a strong correlation ($\rho > 0.912$), when the body volume was reduced, there was an increase in the vertical jump by lower gravitational resistance [12]. Despite the correlation, the independent variables did not show multicollinearity ($p > 0.05$), which allowed them to be used in a multiple linear model [41]. The data for all variables had a normal distribution ($p > 0.05$). The linear trend over time of the variation of the Center of Mass certified that the activity improved the students' physical capacities, according to [8].

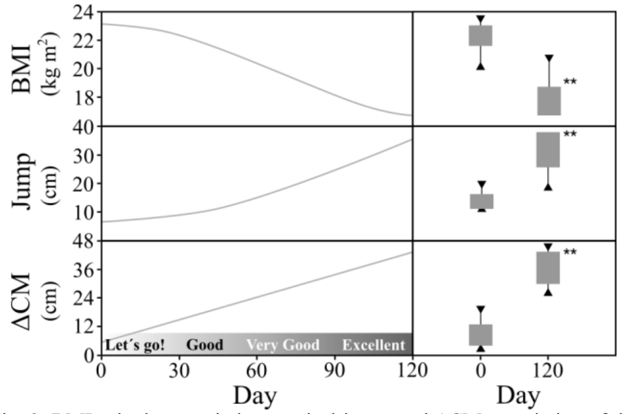

Fig. 3. BMI = body mass index, vertical jump, and ΔCM = variation of the center of mass over the 120 days of challenge, where the students perform 1,000 jumping jacks daily. * Scale is the qualification of the status regarding the student's activity and the biometric consequence of that activity. ** p < 0.001 result of the T Test paired between #Day0 and #Day120.

The multiple linear mathematical model found obtained significance in all adjusted coefficients ($p < 0.001$) and in the determination coefficient (R^2 = 0.98), and obtained an adjustment error of less than 2%, including normalities of the possible growth of students (2).

$$\Delta CM = 232.01 - 9.35 \cdot BMI - 1.21 \cdot \text{Vertical Jump } (\pm 0.018) \qquad (2)$$

Based on this mathematical model, the interactive model “Change your Center of Mass!” was built (Fig. 4). Students and teachers can add data in the fields of independent variables and observe on the ΔCM scale what their qualifications are regarding the student's activity and the biometric consequence of that activity.

41 teachers from the Municipal Public Schools evaluated the Interactive Model and all highlighted the potential of this educational object and scored it with high weights (> 8 = Very Good) in all CAPES criteria [46] for the evaluation of the Technical and Technological Product: impact, complexity, innovation and applicability (Fig. 5). What the teachers highlighted that the challenge moved the student in the individual and collective sphere.

Individual, because of the students at the moment of the challenge viewed and associated in a quantitative (biometric variables) and qualitative (e.g. feeling of disposition) changes in their physical and mental data. This association of two different analyzes (quanti-quali) is an incentive for the student to change on the Piagetian cognitive stage, from the Concrete operational stage (concrete logical analysis) to the Formal operational stage (hypothetical deductive thinking) [16]. This activity can be classified as the beginning of the consolidation of scientific literacy for the student [48], [17].

And collectively, because at the same time, the student observed and communicated with other participants in the challenge, which motivated them by the competition. Socioconstructivist interaction is a potential for individual and collective learning to transform a zone of potential proximal development (activity as a “means”) to real (activity as an “end”) [10].

In the context of physical and mental health, the teachers emphasized the importance of physical exercises for the cognitive development and academic performance of students, that corroborated to the literature that investigated students in detention environments [49], [50], and mainly for the studied moment of closure by the pandemic [4], [5].

Teachers pointed out that a possible limitation of the Interactive Model could be its meta-construction. As it is based on an adjustment of data to a mathematical model, few teachers would have the competence to change the decision tree on the Excel Platform to try to apply the Model with other variables. At the same time, that the teachers pointed out this possible difficulty, they highlighted the complex character of the Model, which needs an interdisciplinary team to transform it, which ends up being a positive and essential point in dealing with educational contexts [51].

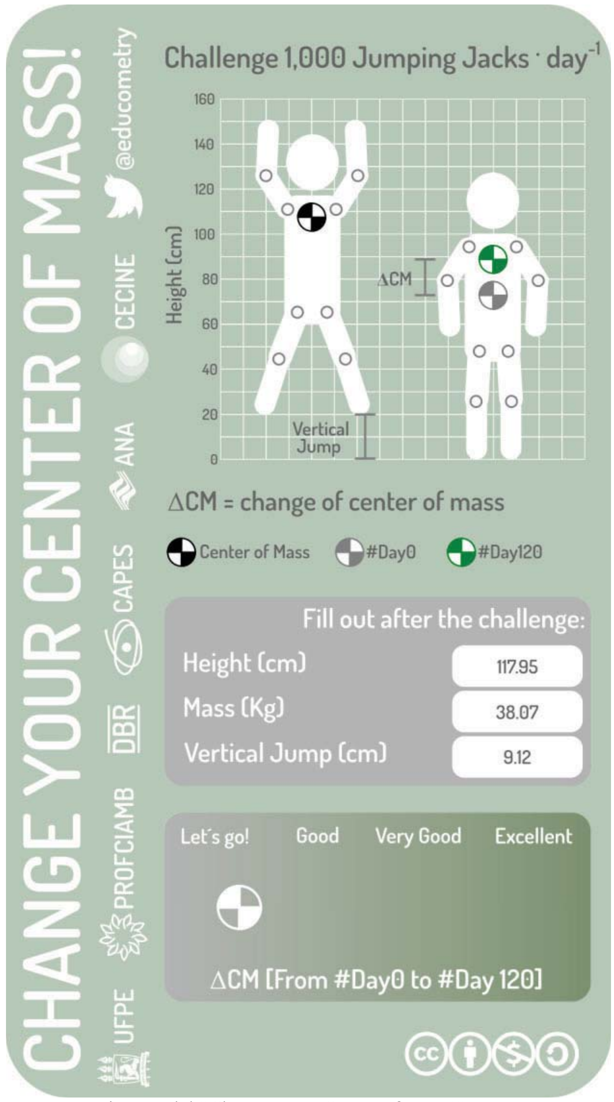

Fig. 4. Interactive Model "Change your Center of Mass!".

At the end of the validation by teachers, everyone stressed the adherence of this Model to the United Nations Sustainable Development (SDG) objectives [52], objective 3 - Health and Well-Being (Ensuring a healthy life and promoting well-being for everyone, at all ages) and objective 4 - Quality Education (Ensuring quality inclusive and equitable education, and promoting lifelong learning opportunities for all) [7]; and to the objectives of the Common National Curricular Base that establishes knowledge, skills, and abilities that all students are expected to develop throughout basic schooling [6].

When comparing the answers to the diagnostic question: What is the word that comes up when you hear about "Center of Mass"? (Fig. 6), the students' responses indicated the change in perception and construction of knowledge about the taught content (from #Day0 to #Day120), closing a teaching-learning cycle in a practical-theoretical way, first to practice and then the consolidation of theory [53]. All the answers went towards what the biophysical variable represents, no students were left behind in the field of building knowledge about the physical concept taught. And this confirms that theories in the field of exact sciences do not have a degree of difficulty that is in the imagination of students, especially in basic education, what is missing is the engagement of students in a direct application of the concept [54], [55], [56], [57], [58], [59].

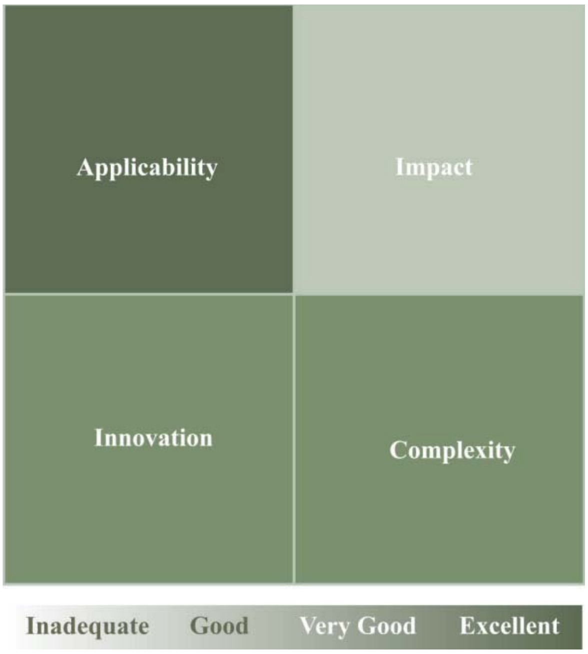

Fig. 5. Evaluation by teachers of the "Interactive Model" based on CAPES Criteria on Technical Production.

Fig. 6. What is the word that comes up when you hear about "Center of Mass"? (A) Question asked before #Day0 and (B) Question asked after #Day120.

IV. Conclusions

The objectives proposed by this project were successfully implemented. The challenge was accepted by students: 1,000 jumping jacks per day and got involved in the study of the physical concept of "Center of Mass". The collected variables were significant and used in the hypothetical mathematical model. The Interactive Model: "Change your Center of Mass!" was built, made available, and evaluated by teachers from Public Schools of Recife City, Brazil.

Teachers highlighted the potential and limitation of the Interactive Model, suggesting the proposal to the educational system by impact, complexity, applicability, and, innovation parameters.

To students, the challenge, the interaction with the model and the final synthesis indicated that the teaching and learning cycle of a biophysical variable is a potential path for individual and collective learning, far from an imaginary that exact science concepts (STEM) may possess a degree of difficulty before it is learned.

Acknowledgment

The authors are grateful to Pro-Reitoria de Pesquisa e Pos-Graduacao of the Universidade Federal de Pernambuco, Coordenacao de Aperfeicoamento de Pessoal de Nivel Superior and Agencia Nacional de Aguas e Saneamento Básico (ANA/CAPES-UAB 2803/2015) for logistical support, and to Research Group 'Educometria' (UFPE/CNPq) for discussion and survey support.

References

[1] World Health Organization. *Emergency*. Accessed: Mar 2020. [Online]. Available: www.who.int

[2] Assembleia Legislativa do Estado de Pernambuco. *Legislação*. Accessed: Mar 2020. [Online] Available: https://legis.alepe.pe.gov.br/covid-19.aspx

[3] Brasil. (2020). *Dispõe sobre as medidas para enfrentamento da emergência de saúde pública de importância internacional decorrente do coronavírus responsável pelo surto de 2019. Lei n° 13.979, de 6 de fevereiro de 2020*. Accessed: Feb 2020. [Online]. Available: www.planalto.gov.br

[4] V. Clemens et al., "Potential effects of" social" distancing measures and school lockdown on child and adolescent mental health," *Eur. Child Adolesc. Psychiatry*, vol. 29, pp. 739–742, 2020. doi: 10.1007/s00787-020-01549-w

[5] J. Lee, "Mental health effects of school closures during COVID-19," *Lancet Child Adolesc. Health*, vol. 4, no. 6, pp. 421, 2020. doi: 10.1016/S2352-4642(20)30109-7

[6] Base Nacional Comum Curricular. (2018). *Educação é a base.* Accessed: Mar 2020. [Online]. Available: http://basenacionalcomum.mec.gov.br

[7] Q. Tang, *Educação para os Objetivos de Desenvolvimento Sustentável: objetivos de aprendizagem*. Paris, France: UNESCO, 2017.

[8] M. I. Croskey et al, "The height of the center of gravity in man," *Am. J. Physiol.-Legacy Content*, vol. 61, no. 1, pp. 171-185, 1922. doi: 10.1152/ajplegacy.1922.61.1.171

[9] J. N. Barham, *Mechanical kinesiology.* St. Louis, USA: Mosby, 1978.

[10] L. S. Vigotsky, *A formação social da mente: o desenvolvimento dos processos psicológicos superiores*. 7. ed. São Paulo, Brasil: Fontes, 2007.

[11] Biophysical Society. (2020). *The Biophysicist*. Accessed: Jun 2020. [Online]. Available: biophysics.org/the-biophysicist

[12] C. E. Palmer, "Center of gravity of the human body during growth. I. An improved apparatus for determining the center of gravity," *Am. J. Phys. Anthropol.*, vol. 11, no. 3, pp. 423-455, 1928. doi: 10.1002/ajpa.1330110302

[13] C. E. Palmer, "Studies of the center of gravity in the human body," *Child Dev.*, vol. 15, no. 2/3, pp. 99-180, 1944. doi: 10.2307/1125537

[14] J. F. Drazan, “Biomechanists can revolutionize the STEM pipeline by engaging youth athletes in sports-science based STEM outreach,” *J. Biomech*, vol. 99, e-109511, 2020. doi: 10.1016/j.jbiomech.2019.109511.

[15] Cambridge Dictionary (2020), *Jumping Jack.* Accessed Mar 2020. [Online], Available: dictionary.cambridge.org

[16] J. A. Piaget, *A epistemologia genética.* Petrópolis, Brazil: Vozes, 1971.

[17] O. A. Santana, and Y. Petrova, “Ludicidade no Ensino da Normalidade em um Ambiente Florestal,” *Inter-ação*, vol. 41, pp. 525-544, 2016. doi: 10.5216/ia.v41i3.41502

[18] O. A. Santana et al., “Árvores potenciais a danos urbanos: manejo através da tecnologia, educação e mobilização social,” *Rev. Tec. e Soc.*, vol. 11, pp. 71-88, 2015. doi: 10.3895/rts.v11n23.2748

[19] O. A. Santana et al., “Aerial survey of nonstandard firewood consumption in urban areas,” In: *2019 IEEE Green Technologies Conference(GreenTech)*, 2019, Lafayette. 2019 IEEE Green Technologies Conference(GreenTech). Lafayette, LA: IEEE, 2019. v. X. p. 1-4. DOI: 10.1109/GreenTech.2019.8767160

[20] C. Lima et al., “Pré-diagnóstico da esquistossomose no semiárido: régua antropométrica e aplicativo colaborativo,” *Rev. Tec. e Soc*., vol. 15, pp. 272-293, 2019. doi: 10.3895/rts.v15n36.7809

[21] A. Konosu et al., “Radial Movements and Lower Limb Joint Kinematics during the Takeoff Phase of Kicking Pullovers,” *Int. J. Sci. Med. Sport and Health Sci.*, vol. 33, e-201933, 2019. doi: 10.5432/ijshs.201933

[22] J. Y. Keum, and D. H. Kim, “An Effective Teaching Method for the Centroid of Triangle in Middle School Mathematics,” *East Asian Math. J.*, vol. 29, no. 4, pp. 425–447, 2013. doi: 10.7858/eamj.2013.029

[23] L. Chen, P. Chen, and Z. Lin, “Artificial Intelligence in Education: A Review,” *IEEE Access*, vol. 8, pp. 75264-75278, 2020. doi: 10.1109/ACCESS.2019.2956136

[24] T. Hodgson, and D. Schultz, “A Refreshingly Rational Approach to the Center of Mass,” *Math. Teach.*, vol. 108, no. 9, pp. 710-715, 2015. doi: 10.5951/mathteacher.108.9.0710

[25] P. House, “Science and Mathematics in Balance,” *Math. Teach. Middle Sch.*, vol. 11, no. 9, pp. 453-459, 2006. doi: 10.5951/MTMS.11.9.0453

[26] D. Kim, and M. Ju, “A changing trajectory of proof learning in the geometry inquiry classroom,” *ZDM Math. Educ.*, vol. 44, pp. 149–160, 2012. doi: 10.1007/s11858-012-0411-4

[27] A. Irgens et al., “Modeling and Measuring High School Students’ Computational Thinking Practices in Science,” *J. Sci. Educ. Technol.*, vol. 29, pp. 137–161, 2020. doi: 10.1007/s10956-020-09811-1

[28] A. M. Leavy, and J. A. Middleton, “Elementary and middle grade students’ constructions of typicality,” *J. Math. Behav.*, vol. 30, no. 3, pp. 235-254, 2011. doi: 10.1016/j.jmathb.2011.03.001

[29] H. B. Yanik, “Prospective middle school mathematics teachers’ preconceptions of geometric translations,” *Educ. Stud. Math.*, vol. 78, pp. 231–260, 2011. doi: 10.1007/s10649-011-9324-3

[30] H. D. Jo, “Kinematic Comparative Analysis of Long Turns between Experienced and Inexperienced Ski Instructors,” *Korean Soc. Sport Biomech.*, vol. 30, no. 1, pp. 17–25, 2020. doi: 10.5103/KJSB.2020.30.1.17

[31] A. A. Alhusaini, G. Melam, and S. Buragadda, “The role of body mass index on dynamic balance and muscle strength in Saudi schoolchildren,” *Sci. & Sports*, vol. 11, no. 7, e1016, 2020. doi: 10.1016/j.scispo.2019.11.007

[32] G. Ziv, and R. Lidor, “Vertical jump in female and male basketball players—A review of observational and experimental studies,” *J. Sci. Med. Sport*, vol. 13, no. 3, pp. 332-339, 2010. doi: 10.1016/j.jsams.2009.02.009

[33] Recife. (2020). *Movimento Recife*. Accessed Mar 2020. [Online]. Available: https://movimenta.recife.pe.gov.br

[34] A. Quetelet, *Sur l’homme et le développement de ses facultés*. Paris, France: Bachelier, 1835.

[35] M. Habermann et al., “DeepCap: Monocular Human Performance Capture Using Weak Supervision,” In: *2020 IEEE Computer Vision and Pattern Recognition (CVPR)*, 2020, Virtual. 2020 IEEE Computer Vision and Pattern Recognition (CVPR), 2020. p. 1-12.

[36] O. A. Santana et al., “Deep learning practice for high school student engagement in STEM careers,” In: *2020 IEEE Global Engineering Education Conference (EDUCON)*, 2020, Porto. 2020 IEEE Global Engineering Education Conference (EDUCON), 2020. p. 164-169. DOI: 10.1109/educon45650.2020.9125281

[37] J. H. Zar, *Biostatistical analysis*. 4. ed. New Jersey, NJ, USA: Prentice Hall, 1999.

[38] R. B. D’Agostino, A. Belanger, and R. B. D’Agostino Jr., “A suggestion for using powerful and informative tests of normality,” *Am. Stat.*, vol. 44, n. 4, pp. 316- 321, 1990.

[39] Instituto Mamirauá. (2020). *BioEstat 5.3*. Accessed Mar 2020. [Online]. Available: mamiraua.org.br.

[40] World Health Organization. (2020). *Growth reference data for 5-19 years.* Accessed Mar 2020. [Online] Available: www.who.int/growthref/en

[41] D. C. Montgomery, E. A. Peck, and G. G. *Vining, Introduction to linear regression analysis*. 4. ed. New York, USA: John Wiley & Sons, 2006.

[42] R. Braithwaite, C. M. Spray, and V. E. Warburton, “Motivational climate interventions in physical education: A meta-analysis,” *Psychol Sport. Exerc.*, vol. 12, no. 6, pp. 628-638, 2011. doi: 10.1016/j.psychsport.2011.06.005.

[43] Microsoft 365. (2020). *Microsoft Excel*. Accessed Mar 2020. [Online]. Available: www.microsoft.com/pt-br/microsoft-365/excel.

[44] A. McFadden, and K. E. Williams, “Teachers as evaluators: Results from a systematic literature review,” *Stud. Educ. Evaluation*, vol. 64, 2020, e-100830. doi: 10.1016/j.stueduc.2019.100830.

[45] J. Davies (2020), *Word cloud generator*. Accessed Jan 2020. [Online]. Available jasondavies.com/wordcloud.

[46] CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (2019) *Produção Técnica*. Accessed Mar 2020. [Online]. Available: https://cutt.ly/yp80w8F

[47] R. Likert, “A technique for the measurement of attitudes,” *Arch. Psychol.*, vol. 22, pp. 140-155, 1932.

[48] G. Fourez, *Alfabetización científica y tecnológica: acerca de las finalidades de la enseñanza de las ciencias.* Madrid, Spain: Ediciones Colihue, 1997.

[49] J. Flores et al., “High points of learning behind bars: Characteristics of positive correctional education experiences for incarcerated girls,” *Int. J. Educ. Dev.*, vol. 77, e-102210, 2020. doi: 10.1016/j.ijedudev.2020.102210

[50] D. Litz, R. B. Hourani, and S. Scott, “Leadership challenges in an educational program at a UAE juvenile detention center: A contextual analysis,” *Int. J. Educ. Dev.*, vol. 76, e102193, 2020. doi: 10.1016/j.ijedudev.2020.102193

[51] E. Leff, *La complejidad ambiental*. México: Siglo XXI/UNAM/PNUMA, 2000.

[52] UN – United Nation. (2020). *Sustainable Development.* Accessed Fev 2020. [Online]. Available: www.un.org/sustainabledevelopment/

[53] L. J. Malkiewich, and C. C. Chase, “What’s your goal? The importance of shaping the goals of engineering tasks to focus learners on the underlying Science,” *Instr. Sci.*, vol. 47, pp. 551–588, 2019. doi: 10.1007/s11251-019-09493-2

[54] O.A. Santana, G. Cuniat, and J. Imana-Encinas, "Contribution of understory vegetation on total evapotranspiration in distinct environments of the Cerrado Biome, Distrito Federal, Brazil," *Cienc. Florest*., vol. 20, pp. 269-281, 2010. doi: 10.5902/198050981851

[55] O.A. Santana, "Social Resistance in the Arid Caatinga: The Narrative of those who Remained in the Environmental Collapse," *Desenvolv. Meio Ambient*., vol. 38, pp. 419-438, 2016. doi: 10.5380/dma.v38i0.43574

[56] K.D. da Silva, O.A. Santana, and S.R.A. de Moraes, "Quality and Language of Learning Objects Used in the Teaching of Human Anatomy," *Int. J. Morphol*., vol. 31, pp. 455-460, 2013. doi: 10.4067/S0717-95022013000200015

[57] O.A. Santana et al., "Relationship between redness index of soil and carbon stock of aerial biomass in Cerrado vegetation," *Cienc. Florest*., vol. 23, pp. 783-794, 2013. doi: 10.5902/1980509812362

[58] O.A. Santana, "Dropout in the licentiates to teaching undergraduate courses of Federal Universities: between inclination and competency," *Educ*., vol. 41, pp. 311-327, 2016. doi: 10.5902/1984644420199

[59] C. Lima et al., "Pre-diagnosis of schistosomiasis in the semi-arid: anthropometric ruler and collaborative application," *Rev. Tec. e Soc*., vol. 15, pp. 272-293, 2019. doi: 10.3895/rts.v15n36.7809