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SUMA EDUCATIONAL FRAMEWORK: THE WAY TO EMBODIED TRANSDISCIPLINARY KNOWLEDGE TRANSFER

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Abstract
Contemporary education, based on a fragmented structure of topics, limits reasoning and critical thinking in students, contributing little to the development of the integrative competencies and knowledge considered essential in modern society. Interdisciplinary approaches give raise to new specialties, but do not reduce the barriers within and between STEM (Science, Technology, Engineering and Mathematics), Humanities and Arts. The proposal of the SUMA (Synthetic Understanding through Movement Analogies) educational framework is applying movement analogies to learn the unifying concepts of science, that is, concepts that persist despite the changes of scientific paradigms or theories, and have a pluri-contextual character. This way, the SUMA framework aims to capitalize on the current perspective of cognitive science that defines cognition as ecological, embodied and enactive, and emphasizes body movement as a means to acquire abstract concepts. After explaining the origins, rationale, ongoing research and supporting tools (learning platform) of the SUMA educational approach, the proposed learning phases illustrate the differences between the more known interdisciplinary physical education and the current approach.

Key Words*: SUMA educational framework, STEM, Humanities, Arts, transdisciplinary mobility, movement analogies, general principles*

Introduction

The SUMA educational framework (Hristovski, 2013) stands for Synthetic Understanding through Movement Analogies and aims at developing an integrated framework for understanding phenomena spanning from physics to sociology and arts. The SUMA project, as a line of research within the SUMA educational framework, is a product of cooperation between the Faculty of Physical Education, Sport and Health, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia, and the Complex Systems in Sport Research Group, INEFC, Univ. Barcelona, the project can be followed through the online Integrative education-learning platform (suma.edu.mk).

The SUMA project has participated in different editions of the Science Festival of the University of Barcelona under the auspices of UBICS (University of Barcelona, Institute of Complex Systems) and under the general theme of Discovering Complex Systems with different topics: "SUMA project: Synthetic Understanding through Movement Analogies", 2018; "Learning transdisciplinary concepts through movement analogies", 2019; "Move to discover complex systems", 2020. Its research line "Towards an embodied and transdisciplinary education" has been granted by the Ministerio de Educación y Formación Profesional of the Spanish government (FPU19/05693). As part of the research program, and in collaboration with the education institute INS María Rúbies from Lleida (https://agora.xtec.cat/iesmariarubies/) and the foundation Empieza x Educar (http://programaexe.org), a new curricular optional topic for secondary school "Move to understand the world" has been created. The project represents a first attempt to apply SUMA educational approach in the official education curriculum, and the ongoing research aims testing its impact: a) on the integrative competencies of students and teachers and b) on the knowledge transfer among topics related to STEM, Humanities and Arts. The final purpose of the program is enlarging the scientific-technical experience to all education levels (primary, secondary school and university) and diffusing the research results of the embodied and transdisciplinary education experiences among the education community.

Why an integrated understanding in education?

The search for minimum principles that explain the maximum number of phenomena is a tacit motive in science. Although integration of knowledge has been proved as a successful strategy for scientific development, the tremendous growth of science has mostly produced further specialization and fragmentation. Therefore, modern education from its initiation has been fragmented. Long before the onset of post-modern movement in the 1960es and 70es (e.g. Lyotard, 1979), during and after the period of Enlightenment, various education systems lend themselves to immersing young generations within fragmented narratives told by different academic subjects. Today the situation is not different.

In his UN manifesto 'Seven complex lessons in education for the future', Edgar Morin made a plea for an integrated approach in education. In his view, the contemporary education, based on a fragmented structure of topics, limits reasoning and critical thinking in students, contributing little to the development of the integrative competencies and knowledge considered essential in modern society. However, the problem relies on how to *genuinely* integrate STEM, Humanities and Arts.

Integration of STEM, Humanities and Arts

The integration and reduction of barriers within and between widely different areas as STEM, Humanities and Arts cannot be achieved by various forms of multidisciplinary and interdisciplinary approaches as usually considered. Most of the multidisciplinary, interdisciplinary and transdisciplinary approaches are *problem-centred* and entail diverse theories, data-acquisition, analysis techniques and modes of inquiry to study a problem (phenomenon), the object of research or applicative intervention. It is a kind of many-to-one mapping logic. In contrast, the transdisciplinarity underpinning the SUMA education approach is *unificatory-understanding-centred* and proposes that the same meta-theoretical framework (general concepts and principles) are used in diverse problems (phenomena), objects of research and practices studied by diverse disciplines. In short, it is a one-to-many mapping logic.

General concepts and principles, representing the spine of academic disciplines and defined in the learning platform of SUMA (https://suma.edu.mk/general-concepts/), have been first formulated in mathematics and physics, and concretely, they are ascribed to the Dynamic Systems Theory (DST) and Statistical Physics (SP), theories that capture, study and explain the system's changes over time as well as structural and functional transitions occurring in complex systems at different scales when interacting with the environment. In this way, DST and SP offer a common language, which can provide a unified framework for science, and thus, contribute to promote transdisciplinarity and unification of understanding of phenomena. It is worth to remark that DST and SP concepts are not physical although they were firstly applied in physics, but merely general. One can easily envision an alternate history of science in which e.g. sociologists first model the collective behaviour of humans or animals and then, 100 years later, physicists become aware that the same principle is valid for the emergence of e.g. macroscopic magnetism. Therefore, what is relevant in the SUMA educational framework and particularly, the SUMA project, is the generality of principles and concepts found in nature.

A common language for understanding Nature and Arts?

Science communities explore and strive to explain the immense diversity of processes observed at different levels and time scales of substance organization in nature. As the key properties of each level cannot be formal, i.e., mathematically, deduced from the laws that govern the behaviour of the more microscopic components (Hristovski, 2013, Hristovski, Balagué and Vázquez, 2014, 2019), different scientific disciplines have emerged (see Fig 1). The diversity of levels and phenomena constrains the scientific language of each discipline to form a specific vocabulary for naming and explaining the properties and processes under study, as well as communicating knowledge among scientists. This is how cosmologists speak about inflationary and electroweak epoch and space-time metrics, cell biologists about organelles, enzymes and metabolic pathways, psychologists about stress, emotions and personality, and sociologists about group formation, cohesion and leadership. These languages, thus, use context-dependent concepts to name and explain the processes under scrutiny. Context dependence is viewed essentially as a major cause of the fragmentation between the vocabularies of different scientific disciplines. While within specific scientific fields and subfields the communication of knowledge is made possible by a common vocabulary, the more distant disciplines are, the more difficult communication becomes. As this language fragmentation is also translated into science education, this inevitably leads to the formation of a fragmented worldview in learners and limits the possibilities of a learning transfer between different scientific subjects.

This is how the high disciplinary specialization and the development of context-specific science languages have entailed a lack of communication and transfer of knowledge among scientists (Hristovski, 2013). It is in such context that the SUMA educational framework suggests applying movement analogies (Hristovski, Balagué & Vázquez, 2014) to learn the unifying concepts of science provided by the DST and SP. Such concepts are increasingly used in a wide spectrum of scientific disciplines, and particularly, are useful to understand the behaviour of simple, as well as, of complex dynamic systems.

The tension arising from the coexistence of context-dependent and unifying tendencies in science can be seen as an opportunity rather than a problem: resolving it may result in patterns of understanding that are characterized by both a coherent explanatory skeleton coming from unifying tendencies and flexibility due to its context-dependent vocabulary. Their interplay is, what we consider, the necessary ingredient of building a coherent and yet flexible understanding of the world we live in.

From the point of view of scientific practice (in STEM areas but also Humanities and Arts), the importance of solid understanding and use of general unifying concepts cannot be overestimated. They are nested at each level of substance organization, persist despite the changes of scientific paradigms or theories, and have a pluri-contextual character, representing the spine of all sciences (Hristovski, Balagué & Vázquez, 2019).

The last 20-30 years witnessed immense disciplinary mobility of machine learning and dynamic systems approaches and modeling tools, which are thoroughly based on the application of the general (i.e. pluri-contextual) unifying concepts (e.g. stability, attractor, gradients, symmetry etc.), to areas that were separate before (see Figure 1). Today, one can find scientists who use these tools and hence principles and concepts, in a wide area of academic research areas, starting from physics, to molecular and cell biology, to neurosciences, psychology and exercise and sports sciences. In this way, many scientists can escape the confines of its discipline and join research in other, previously distant, domains. This capacity of evading and escaping the state of confinement and reduced possibilities of achieving the goal has been recently defined as a hallmark of the adaptive behaviour (Hristovski and Balagué, 2020).

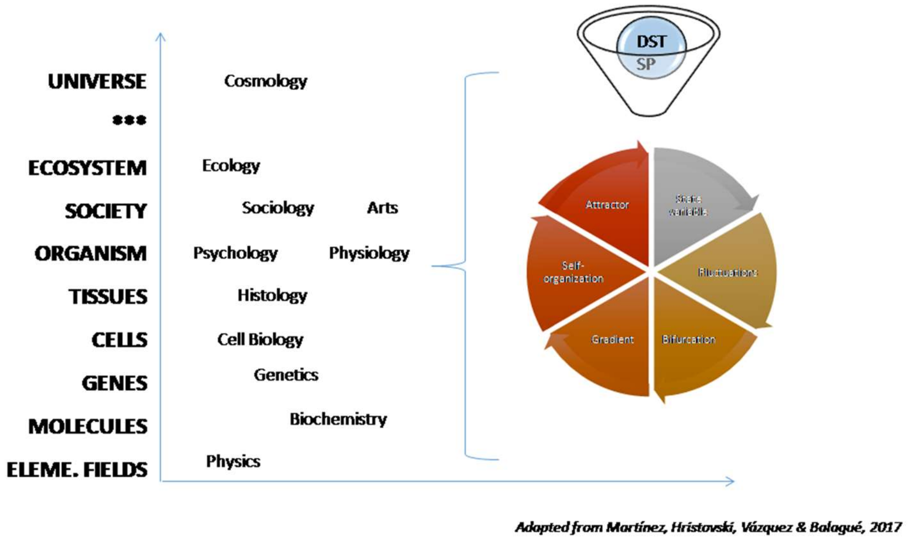

Figure 1. General concepts and principles from the Dynamical systems theory (DST) and Statistical Physics (SP) are at the heart of mathematical modeling and understanding in STEM and Humanities. Adapted from Martinez, Hristovski, Vazquez and Balague, 2017. With courtesy of Frontiers in Psychology).

What can be found in the Integrative education learning platform of SUMA?

The learning platform of SUMA educational framework aims to provide one strategy for building a synthetic understanding of the processes in Nature.The integrative focus is based on teaching common concepts and principles extant in various dynamical systems. Moreover, physical activities, in a form of movement analogies, are the pivot of such an integrative education which provides an embodied and experientially grounded understanding. The main aim is providing a helping tool for teachers, educators and students in their permanent striving to integrate their visions of the world. The visitor can find:

- *The Big Picture*: A general view on 'How Nature works' that leads to synthetic understanding and worldview.
- *General Concepts and Principles*: Integrative dynamic concepts used to teach and understand processes through textual explanations, simulations, animations and movement analogies;
- *Phenomena*: Understanding of phenomena existing at different levels of Nature's organization through textual explanations, simulations, animations and movement analogies, based on general concepts and principles.

Is integrated education becoming physical?

Why embodied education? The current perspective of cognitive science defines cognition as ecological, embodied and enactive, and emphasizes body movement as a means to acquire abstract concepts (Abrahamson & Sanchez-García, 2016). While currently, under the name of interdisciplinary physical education, there is a rich and elaborated learning strategy applied to disciplines like mathematics, physics, biology, music, or culture (Cone, Wernerand & Cone, 2009), such interdisciplinary approach is not integrative. It does not allow students to learn and experience the *common principles* and *concepts* nested in each of sciences and the relations that sciences have with arts. Instead to use physical activities for understanding processes and phenomena from different sciences, we propose using movement analogies to connect STEM (Science, Technology, Engineering and Mathematics), Social Sciences, Humanities and Arts by focusing on common principles and concepts.

Based on Kolb's (1984) experiential learning approach, and the ecological and embodied learning paradigms (Abrahamson & Sanchez-García, 2016) the proposed learning phases are as follows: 1.Concrete experience (a physical activity: perception-action and/or introspection) 2. Reflective observation on the experience (paying attention to key perceived phenomena and their phases) 3. Abstract conceptualization based upon the reflective observation (conceptualization, estimation and/or plotting of relations)
4. Experimenting with the new concepts and applying them to different fields and phenomena studied in the academic curriculum. These phases can be supported by various types of contexts such as learning in natural settings as well by use of educational technology, such as videos, augmented learning, virtual environments etc. Also, the learning process can take various forms such as individual or cooperative learning.

An example of a practical application of the method

A balance task can be used as a movement analogy to learn general concepts like stability, meta-stability, criticality (instability), search for stability and qualitative change; that may, afterwards, be transferred to diverse phenomena in nature, the social realm, and arts.

Keeping balance in the upright position is a basic motor skill in humans. It needs coordinated cooperation of the neuro-muscular system at many levels to negotiate the major environmental constraint (gravity) which tends to collapse the body. Due to gravity, for the human body, the ground state is the global energy minimum stable state (minimum metabolic rate). All other positions are metastable states that need active control to be stabilized. The degree of stability can be tested by applying external perturbations to the body and observing how it behaves. Rapid recovery of its previous state signifies stability, slow recovery signifies approaching instability, and no recovery at all signifies instability, i.e., loss of stability.

The learner stands with the feet parallel facing a target within reach/just out of reach. S/he is instructed to pay attention to a specific set of bodily sensations that will occur under different conditions. The distance from the target is divided into 10 equidistant intervals. The scaled target distance D is calculated as a ratio between the physical distance of the learner from the target to his/her arm length measured from the shoulder to the fingertips. The physical distance is measured from the tips of the toes to the vertical projection of the front part of the target on the floor. Starting from the closest scaled distance, the learner tries to reach and touch the target. Also, at each scaled distance, a partner applies a relatively constant mechanical perturbation to the learner's trunk in the direction of the target. As the scaled distance increases, typically close to $D = 1.4$, the learner loses balance and takes a step forward, i.e. transits to a more stable diagonal stance.

The learner is asked to provide several self-reports on the sensations of stability perceived at different scaled distances D, especially to the perturbations applied by the partner and the behavioural variability of the lower limbs and the centre of mass. The whole procedure may be videotaped and essential variables may be estimated, such as the centre of mass displacement and the leg displacement, and then put to further use. The concept of stability may be studied also in a perceptually grounded fashion with inanimate mechanical bodies as well, with learners acting and observing the effects produced on the body. However, important phenomena like the enhancement of fluctuations close to the critical point will not be obtained in this case.

The concept of stability exists because the behaviour or structure recovers quickly after a small perturbation. Hence, the behaviour/structure exists because it is insensitive (robust) to perturbations coming from within or out of the system. The competition of bond-forming couplings and perturbations is present in any system we see. Stability is reached if couplings between the components of the system are larger than the internal or external perturbing forces trying to decouple them, and vice versa. Nature creates and destroys through instabilities and maintains through stability. For instance, a human-made building is stable when the bond couplings resist the common earth crust tremblers. However, those stable couplings can be destroyed during an earthquake of high intensity. Some examples, of how perturbations induce instabilities which produce structures out of homogeneous stable state are Rayleigh-Taylor instability, Plateau-Rayleigh instability, Kelvin-Helmholtz instability liquid-solid transitions of supercooled liquids etc.

Conclusion

The SUMA approach can be used by physical education teachers or other specialists, though not necessarily during the physical education lessons, quite possibly through other forms of curricula (e.g. a *separate subject* (Hristovski, 2013) with the content of the SUMA educational framework), can contribute to 1) help teachers and students to discover and learn the unifying concepts common to STEM, Social Sciences, Humanities and Arts, 2) overcome the limits of fragmentation in education promoting an integrated scientific understanding, 3) overcome the lack of tune between contemporary scientific knowledge and educational practice,4) provide a transdisciplinary *transfer of knowledge* and enhance the *transdisciplinary mobility* of researchers in science, humanities and the arts, and 5) contribute to building a synthetic worldview and an integrated *feeling* of the world, a part that is thoroughly missing in current education. In this way, knowledge and the meaning it is supposed to provide may become genuinely physical through physical activities.

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