PRODUCTIVE METAPHOR OF MOLECULAR ORBITALS IN EDUCATION AND ANY VIABLE THEORY

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A lot has been researched on and published about applying analogies in teaching science. The content being complex, often abstract, and difficult for understanding, analogy comes as an effective tool to catch the essence. In brief, using an analogy for explanation of something unfamiliar new, we take something familiar old and establish connections between the two (Sarantopoulous & Tsaparlis, 2004).

Depending on the audience's prior awareness, one can use not only direct but also inverse analogies. It is when the something unfamiliar for most people (non-specialists) is used for interpretation of something well familiar. In my last editorial (Slabin, 2017), I used the MO theory (Molecular Orbitals are Linear Combination of Atomic Orbitals) college instructors, school teachers, and other chemistry professionals are familiar with, as a metaphor to explain formation and resultant stability of eponyms. Those are word combinations denoting compounds (Lewis acid), glassware (Liebig condenser), phenomena (Tyndall effect), equations (Clapeyron equation), etc., named after their discoverer (designer) and valuable for science education in terms of its humanization. The analogy demonstrated why some eponyms are stable, commonly adopted, popular, and effective in education, while others are merely temporary and situational.

How does the MO analogy work? In simple terms, disregarding underpinning quantum mechanical calculations, it considers two or more original atomic orbitals (AO) and their possible combinations, molecular orbitals (MO), for relative potential energy and stability. The classical case includes two AOs and two MOs:

1. Combination of AOs with compatible symmetry: results in lowering of the system's overall energy, increased stability, and forming a bonding MO.
2. Combination of AOs with incompatible symmetry: results in heightening of the system's overall energy, decreased stability, and forming an anti-bonding MO.

Sometimes a combination of AOs is considered, where their positive and negative interactions mutually compensate each other. It results in unchanged system's overall energy and stability, and forming a non-bonding MO.

If we abstract from AOs and MOs, we see that this approach actually consists of four steps: (1) taking two *inputs*, (2) analyzing them for compatibility, (3) projecting two or three possible *outputs*, (4) making conclusion about relative stability, or viability, or effectiveness of those outputs. One can assume that this approach can be applied to many systems (physical, chemical, biological, geological, asf.) and theories (psychological, pedagogi-

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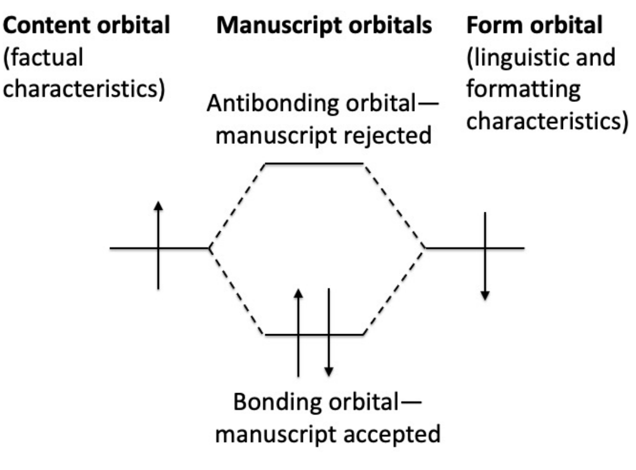
cal, philosophical, etc.). It can be applied as analogy of both objects and relationships. In this simplified form, the MO metaphor does not have to be presented in its classical chemical form—diagram with energy axis and electrons on AO and MO; it becomes a sort of a concept map (Kane & Trochim, 2007), a handy technique for quick evaluation of solutions for their feasibility, stability, effectiveness.

E.g., when two unfamiliar individuals (AO) meet, it can result in a close and long-time friendship (bonding MO), tension and conflict (anti-bonding MO), or indifferent co-existence (non-bonding MO). Of course, these outcomes are idealized extreme states and, as everything in social sciences, are expected with certain statistical probability. Furthermore, unlike real atomic orbitals, people can work and change towards good relationships (bonding MO). But objectively, the MO metaphor predicts that chances for good relationships are greater when the individuals are originally similar, share some common values, and possess other traits that enhance their compatibility. Forming a collective involves many individuals (AO) and results in a much more complex structure. Its examples include a united cohesive team (bonding MO), a dissipated group like occasional bus passengers (non-bonding MO), or a real jar of spiders (anti-bonding MO). A most interesting and important case (and a theoretical input to collaborative pedagogy) would be applying MO analogy to analyze formation of teacher-student groups.

Exemplifying the MO metaphor, consider conducting educational research and authoring a manuscript—say, for the Journal of Baltic Science Education. As multiple inputs (AO) we have the content (factual characteristics, such as research design, literature review, methodology, tools, data collected, statistics used, results obtained, conclusions, references) and the form (linguistic characteristics including style, syntax, and grammar; tables and figures, requirements of American Psychological Association, etc.). As multiple outputs (MO) we have a kind of line spectrum. On its one end is some ideal manuscript, which eventually becomes a scholarly paper and which the editorial board loves the most: smart research design combined with sound methodology, efficacious tools, adequate statistics, reliable results, exhaustive literary review, clear language, and compliance with APA. On the spectrum's another end is some incoherent writing that the editorial board rejects: the manuscript reports research based on lame methodology, employs inadequate statistics, abounds with typos, and ignores APA. Figure 1 illustrates this analysis, grouping multiple inputs into two orbitals: content and form.

Figure 1
Possible Manuscripts Resulting from Combination of Content and Form Inputs



The MO metaphor can act as *analogy of objects* and *analogy of relationships*. As all teaching methods, the MO analogy has apparent limitations. Not being a strict analogy, it can naturally provide mere approximate, probabilistic conclusions. On the other hand, it does not aim at explaining the well familiar (for it is already known) but remains productive because it allows to reconsider, reconceptualize, and uncover new relationships within the system. This re-discovery becomes possible as the system is presented in a simplified way, with only essential features considered.

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