Misrepresenting Emergent Causal Processes as Non-Emergent: A Potential Schema for Overcoming Misunderstandings in Science

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Middle and high school students encounter numerous scientific and "everyday" processes in their curriculum. Some of these processes (e.g., electricity, heat flow, natural selection) seem particularly troublesome for them to learn with deep understanding. One reason for this difficulty is that students often possess alternative conceptions (or misconceptions) that are naïve and scientifically incorrect. These misconceptions are extremely robust and resistant to instruction, therefore preventing students from acquiring the correct understanding.

This paper provides a conceptual analysis that explains why there is a barrier in understanding these processes and what can be done to overcome it. The analysis essentially suggests that these often-misunderstood concepts are bi-level processes in which the global level pattern emerges from the collective individual actions/interactions at the micro level. Thus, the explanatory mechanism that causally relates the micro and the macro levels is an emergent one. Students, however, intuitively misrepresent an *emergent* mechanism as a kind of a non-emergent (or *direct*, for lack of a better term) causal mechanism.

Two types of features of the underlying explanatory mechanisms of *emergent* causal and *direct* causal processes are identified. One type of feature, shown in Table 1, describes the nature of the behavior of the individuals at the micro level. The behavior (i.e., the actions/interactions) of the individuals of an emergent causal process suggest that their actions/interactions must be considered as a *collection*, whereas the behavior of the individuals of a direct causal process suggest that their actions/interactions can be partitioned into distinct *classes*. Thus, this set of six features can serve the purpose of helping students recognize when it is appropriate to consider a set of actions/interactions collectively rather than distinctively.

Table 1: Six features of the actions/interactions (A/I) of individuals in a collection versus classes.

Emergent (Collection)	Non-Emergent (Classes)
● Same kind of A/I	● Different kind of A/I
● Random A/I	● Fixed A/I
● Co-occur or parallel	● Sequential or linear
● Independent A/I	● Dependent A/I
● Uniform status	● Unique or central status
● Ongoing, continuous	● Bounded, terminating

The second set of five features, shown in Table 2, describes the relationship between the micro and the macro levels. These bi-level relational features are the ones that students can appeal to in explaining the causal relationship between the levels. These two sets of features, together, provide a preliminary specification of *emergent* causal and *direct* causal schemas. The claim is that students use their *direct* causal schema to interpret processes with an emergent explanatory mechanism, and therefore misunderstand them.

Table 2: Five features relating the micro individual and macro aggregate level.

Emergent	Non-Emergent
● Indirect	● Direct
● All individuals	● Some of the individuals
● Local & decentralized	● Goal-directed & intentional
● Disjoint	● Corresponding
● Collective summing within each instance of time	● Cumulative summing across time

Several reasons can be postulated for why students commit such misattributions. First, these 11 features, being mutually exclusive, suggest that *emergent* causal and *direct* causal processes may be ontologically distinct; therefore, repairing such misconceptions requires a radical conceptual shift. Second, students may not even realize that they have misrepresented an emergent kind of causal process as a direct kind. Without such awareness, they lack the motivation to seek ways of re-representing emergent processes correctly. Third, students may altogether lack an emergent schema. Without such a schema, students cannot correctly conceptualize an emergent process. Finally, people in general might have a natural predisposition to interpret all events as a direct causal kind.

The implication of this analysis is that teaching students an emergent schema of the underlying explanatory mechanism may allow them to discriminate an emergent kind of causal process from a non-emergent kind, which then may lead to improvements in their understanding of emergent concepts across various disciplines.