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Short communication

Mesoscales: The path to transdisciplinarity

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HIGHLIGHTS

- Propose the importance of mesoscience for transdisciplinarity.
- Discuss three ways of transdisciplinarity.
- Explore the relationship between big data, cloud/super computing, virtual reality and mesoscience.

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ABSTRACT

This article discusses why mesoscales are the path to transdisciplinarity and the possibility of having a common scientific framework for big data, cloud/super computing and virtual reality, based on mesoscience discussed currently in chemical engineering.

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Current global concepts in scientific practice, such as big data, cloud/super computing and virtual reality, are all rooted in real-world complexity. On the other hand, mesoscience, an emerging scientific concept, is also devoted to exploring the complexity at all mesoscales of the world. That is, they are devoted to the same scientific problem, therefore we would predict that all these concepts might share a common framework in terms of scientific context, which is certainly important also for chemical engineering.

The progress in big data [1], cloud/super computing [2], virtual reality [3] and advanced measurements is opening up a new paradigm for scientific research [1], which means that all disciplines today have the opportunities to further develop, of course, including chemical engineering. A tendency that has not been widely recognized is the evolution of science from ***interdisciplinarity***, in which a problem is solved by integrating knowledge from at least two disciplines, to ***transdisciplinarity*** [4–6], in which the exploration is made of the common rules, tools and theories for different disciplines. The above emerging concepts indicate a tendency towards transdisciplinarity at a higher level. However, an effective scientific pathway to achieve transdisciplinarity is yet to be explored.

Mesoscience, being explored in chemical engineering science [7], aims exactly at looking for a path to transdisciplinarity, which encompasses all mesoscale phenomena between element and system scales at different levels of various fields. The assumption is all mesoscale phenomena at different levels in different disciplines are governed by the principle of compromise in competition between dominant mechanisms, and formulated as a multiple objective variational problem, meaning a possible universality for all mesoscales [8]. Such complexity, as represented in big data, cloud computing and virtual reality, provides a clue to the possible identification of a common framework for the emerging concepts through mesoscience or *vice versa*; that is, transdisciplinarity at a global level of science beyond that between different disciplines.

The history of Nobel Prize clearly reveals the increasing interdisciplinarity nature of science. Transdisciplinarity is also on the gradual rise as demonstrated in the Prize awarded for dissipative structures in 1977 [9] and multiscale modeling in complex chemical systems in 2013 [10]. These two awards were both related to complexity science [11] and mesoscale problems, though the

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importance of mesoscales themselves was not very well recognized.

Transdisciplinarity presents itself in different ways, as shown in Fig. 1. It runs across all the sub-disciplines in the same field (Way 1), such as in chemical science; across different kinds of disciplines such as chemistry, physics, biology and so on (Way 2); and across issues that span the whole range of science, such as big data, cloud/super computing and virtual reality (Way 3).

In the field of chemical science, chemistry, chemical engineering and process system engineering usually work rather separately as individual sub-disciplines, at least focusing on different levels of problems. However, it has been recognized that these sub-disciplines all face some common challenges at their respective mesoscales between element scales and system scales [7,8]. For example, the challenge of interfacial and material structure between molecules/atoms scale and bulk material scale for chemistry, the challenge of dynamic heterogeneity within reactors between particle scale and reactor scale for chemical engineering, and the challenge of integrating units in a factory between a single unit scale and environment scale for process system engineering. Furthermore, it has been proposed that phenomena at these three mesoscales are all governed by the common principle of compromise in competition even though they involve quite different mechanisms. Here, competition means extremum tendency while compromise implies that one extremum has to be subject to constraint from another. This principle can be formulated as a multiple objective variational problem. Without compromise in competition, everything would be simple [7]. The objective of transdisciplinarity here is to identify the common principle for different levels or sub-disciplines of the same field, this is Transdisciplinarity Way 1, as shown in Fig. 1. It is believed to be one of focuses for chemical engineering in 21st century [8].

Across different disciplines of science, this principle of compromise in competition might also hold, as indicated by the folding of proteins in biological science [12] and by turbulence in physical science [13]. This type of transdisciplinarity has led to the concept of mesoscience being proposed [7,8], and we expect that mesoscience will be further extended to other scientific fields.

All disciplines of science, as listed in Fig. 1, feature a multilevel nature, and each level has a specific mesoscale. Here, a critical point is how to correctly identify the levels and their corresponding mesoscales [7]. As in the disciplines of chemical and physical sciences, life science also features multiple mesoscales, which are at the levels of protein, cell and organisms. The principle of compromise in competition plays a role in the stability of these mesoscales, such as in shaping the dynamic structure of proteins [12], and limb development [14,15]. The challenge of mesoscales in a variety of fields is attracting increasing attention as the vehicle for "bridging the small scale and the large scale", also in biology [16], cosmology [17], atmospheric science [18], polymer science [19], even in social science [20,21]. With increasing evidence for the universality of this governing principle (for mesoscales), it seems possible that mesoscales might provide a pathway to achieve transdisciplinarity not only within the same scientific field, but across all disciplines of science, that is, Transdisciplinarity Way 2.

Big data, cloud/super computing, and virtual reality are global concepts for all sciences. The goal of each is to reproduce complex phenomena in nature, engineering and society, in which the dominant complexity at mesoscales must be resolved. It means they all share a common framework with mesoscience. This is Transdisciplinarity Way 3, as illustrated in Fig. 1.

Among these three ways of transdisciplinarity, those within a single field and across different disciplines have been studied, while Transdisciplinarity Way 3 encompassing global issues have not. Attention should be paid to study them at the stage of their emerging so as to guide their development in a scientific way, rather than just so-called buzzwords.

Fig. 2 illustrates the possible relationship between big data, cloud/super computing and virtual reality in the framework of mesoscience. All of these concepts are rooted in the complexity of the world and aim at achieving virtual reality or complete resolution of complex phenomena. If the relationship outlined in Fig. 2 holds, then the realization of virtual reality will become a driving force behind a new paradigm of scientific research.

In fact, big data originates from experiments or from sensing complex phenomena in science, engineering, nature and society, and therefore reflects the complexity at mesoscales. It is reasonable to analyze big data with the framework of mesoscience to reproduce original phenomena, and hence, to realize virtual reality

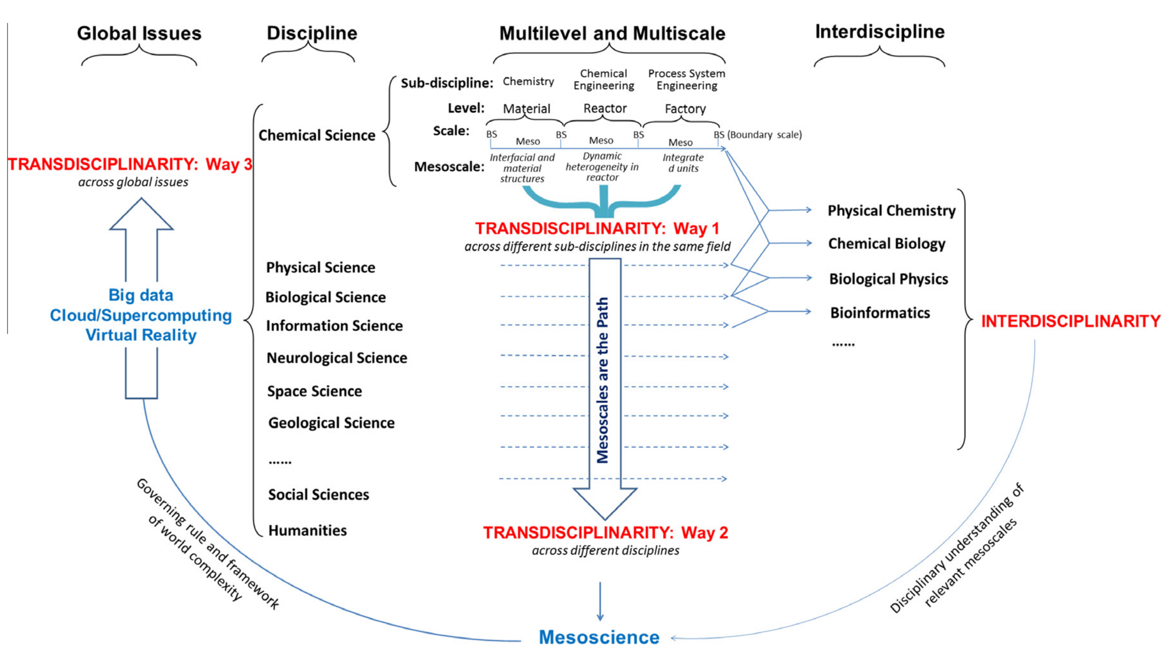

Fig. 1. Transdisciplinarity in three ways: within a single discipline, across multiple disciplines, and across global issues.

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