Social Semiotic Multimodal Research：
A Meaning-based Approach[*]

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Abstract：Multimodal research has attracted increasing interest and set up dialogues with many different disciplines. Based on social semiotic theories of communication，this research examines multimodal representations in scientific discourse with a meaning-based approach to explore the functional specialization of non-verbal modes such as scientific diagrams，the relationships between different semiotic resources in the same text，and the transformation from one mode to another. The present study also responds to several theoretical and methodological issues made of social semiotic multimodal research and discusses the implications of multimodal studies for teaching and learning science.

Key words：multimodality，social semiotics，meaning，science education

社会符号学视角下的多模态研究：一项基于意义的研究方法

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摘要：多模态研究已经成为当今人文及社会科学领域中的热点问题，并且同多个学科建立起对话关系。本文从社会符号学的视角出发，采用基于意义的研究方法，对科学语篇中的多模态表征进行系统分析。分析范围包括诸如科学图像等非语言表征的功能特性，同一语篇中不同符号系统之间的关系，以及不同模态之间的转化过

程。针对外界对多模态分析的理论和研究方法提出的问题和质疑，本文也将作出回应，并讨论多模态研究给科学教育带来的启示。

关键词：多模态，社会符号学，意义，科学教育

Ⅰ. Introduction

The multimodal landscape of communication has attracted a growing attention from scholarship in the past decade. On one hand, new academic publications (e. g., the journal of *Multimodal Communication*) emerged as a regular forum for exploring different representational forms; on the other hand, multimodal studies were increasingly published in reputable linguistics journals (e. g., *Language Sciences*), which used to accept researches on language only.

One problem with existing multimodal research, however, lies in its underdeveloped theories. As Jewitt cautioned, multimodality at the current stage is far from a full-fledged theory but a domain of inquiry influenced by a wide range of disciplines such as sociology, art history, and cultural studies (2009a, p. 2). While these theories are useful to examine some aspects of multimodality, they do not provide research tools for analyzing the full range of representations and thus have limitations to develop a comprehensive theory of multimodality.

In contrast, social semiotics conceptualizes all forms of semiosis with a meaning base. Namely, language along with painting, sculpture and so on is considered one of many modes of meaning, all of which interrelate to constitute human culture (Halliday & Hasan, 1985, p. 4). The meaning-based approach has been strongly linked with multidal studies since the 1990s, as evidenced by the steadily increased social semiotic research on displayed art (O'Toole, 1994), visual design (Kress & van Leeuwen, 1996), music (van Leeuwen, 1999), and mathematical discourse (O'Halloran, 2005), to name just a few.

This paper aims to further develop multimodal theories from a social semiotic perspective. The next section briefly introduces the meaning-based approach and its key theoretical underpinnings for multimodality. Then two main areas of meaning-based multimodal research are described: meaning

making within the same mode and meaning making across different modes. Given that multimodal research has attracted much attention from science education scholars, the analysis of meaning in multimodality is demonstrated through a reference to scientific discourse. This research also responds to several recent criticisms of social semiotic multimodal research. Finally, the present study discusses the pedagogical implications of multimodality.

Ⅱ. Key Tenets of A Meaning-based Approach

Social semiotics is the study of sign systems wherein each choice of sign acquires its meaning against the background of other sign choices not within the sign system itself but in the context of specific social situations (Halliday & Hasan, 1985, p. 4). The meaning-based approach to multimodality has three key theoretical assumptions, which are briefly explained below.

First, meaning is both a social and representational phenomenon, which implies stratification of semiotic systems at different levels of abstraction (Halliday & Matthiessen, 1999, pp. 3-7). For instance, when human beings make a speech to communicate, the meaning is shaped by social norms and the moment by moment situation at the more abstract level (the context stratum), organized in specific language forms and structures, and ultimately expressed in certain sound patterns at the more concrete levels (the lexicogrammar stratum and the expression stratum respectively). A meaning-based interpretation adopts a bottom-up approach and highlights the grammatical construction of meaning, especially in the analysis of language.

Secondly, every communicative practice, in which one or multiple semiotic resources may be deployed, has three kinds of meaning or serves three generalized semiotic functions (metafunctions) simultaneously: to construct "doings" or "state of affairs" in the world as ideational meaning, to take a stance towards the presentation and to the reader/viewer as interpersonal meaning, and to organize related elements into a coherent message as textual meaning (Halliday & Matthiessen, 2004, pp. 29-31). In fact, the shared metafunctional principle has been identified by O'Halloran as the major strength of social semiotic theories for multimodal discourse analysis (2008, p. 444), for it not only provides analytical tools to explore

how modalities other than language make meaning，but also enables semantic integration between different semiotic choices.

Thirdly，meaning operates through time in an ever-changing process called semogenesis（Halliday & Matthiessen，1999，pp. 17－18）. The semogenetic view has been recently extended beyond language to explore the change across different semiotic choices. In the pioneering research on mathematical discourse，O'Halloran adopts a historical perspective and convincingly argues that modern mathematical symbolism grew out of written language and developed a range of specialized lexicogrammatical devices to realize semantic expansions，thereby explaining the complexities of mathematical reality outstripping the meaning potential of language（2005，pp. 94－97）.

Ⅲ. Two Main Areas of Meaning-based Multimodal Research

There are two main areas of meaning-based multimodal research considering the number of modes under investigation. Multimodal studies have been undertaken to explore the functionality of individual modes other than language and the semantic interaction between two or more semiotic resources in communication. The present section does not intend to make an exhaustive list of multimodal research，but only discusses those studies which have been adopted to inform science teaching and learning.

1. Meaning Making within the Same Mode

As mentioned earlier in Section Ⅱ，the shared metafunctions actually provide a common platform to conceptualize all forms of semiosis. Due to the space constraints，this paper only focuses on the ideational metafunction of representations.

From a multimodal perspective，non-verbal modalities can be modeled as systems of interrelated options to make meaning，thereby offering a degree of prediction in how semiotic resources will be designed for communication in specific situations. For example，the ideational meaning options of visual representations can be mapped out through the mechanism of system networks as follows：
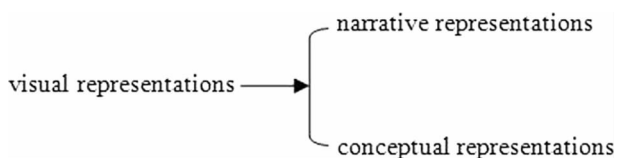
Figure 1 Basic System of Visual Representations

Figure 1 presents a basic network of visual structures. Reading from left to right，visual representations (the entry condition to this system) fall under either the category of narrative representations or the category of conceptual representations. The left-to-right direction of the network also indicates an increasing scale of delicacy. Formulation of systemic networks such as Figure 1 is intended to explicitly account for the meaning potential of semiotic resources，which raises an issue for some researchers nevertheless. This issue will be responded to in Section Ⅳ，I.

According to Halliday and Matthiessen，a linguistic systemic choice is realized by the presence of structural elements (2004，pp. 20－24). For instance，*transitivity* is the grammatical system to model experience as "a manageable set of process types" to represent some kind of the complex "goings-on" in the world (Halliday & Matthiessen，2004，pp. 170－178). One systemic choice of *transitivity* is a material process，which construes the meaning of "doing" or "happening". A material process (e. g. *Particles move at a high speed*) can be organized through a simplified structure "participant ˆ process ˆ circumstance" ("ˆ" means *followed by*).

Likewise，the systemic option of visual *transitivity* is manifested in visual structures (Kress & van Leeuwen，1996，pp. 43－45). For example，the choice of narrative representation in Figure 2 shares similar structural configurations with the material process (*Particles move at a high speed*). However，it is important to note that the same semantic categories have different forms of realization in language and visual images. They also operate at different grammatical ranks.
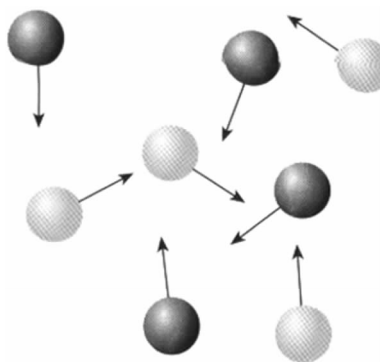
Figure 2 **Visual Representation of Particle Movement**[①]

To illustrate，the material process（*Particles move at a high speed*）operates at the rank of clause in language whereas the visual representation in Figure 2 does at the rank of figure[②]．Furthermore，the semantic categories of participant and process operate at the grammatical rank of word in the form of a noun（*particles*）and of a verb（*move*）respectively．The meaning roles of participant and process are visualized as small circles and arrows at the rank of member in Figure 2．

Also noteworthy is that language and images do not make exactly the same meaning．For example，the colors of the circles（in the original）in Figure 2 indicate that there are two different kinds of particles under investigation．This meaning cannot be found in the corresponding clause（*Particles move at a high speed*）．

Kress explains that different modes have unique meaning-making resources and thus have specific "epistemological commitments"（unavoidable affordances）（2003，p. 3）．Lemke（1998）further distinguishes between two aspects of the ideational meaning：meaning by kind and meaning by degree，and contends that although all semiotic resources can construe both typological meaning and topological meaning，they are good at one of the two types of meaning only．

[①] Figure 2 is reproduced from Onn，H. L.，Ang，E. J. A.，and Khoo，L. E.（2006，p. 199）．

[②] In O'Toole's analytical framework，a figure is a visual rank construing simple "goings-on" in the world．The rank of figure is made up of members at the lowest level（1994，p. 11）．

Language，as a typologically oriented semiotic resource，is unsurpassed as a tool for the formulation of difference and relationship，for the making of categorical distinctions. It is much poorer（though hardly bankrupt）in resources for formulating degree，quantity，gradation，continuous change，continuous co-variation，non-integer ratios，varying proportionality，complex topological relations of relative nearness or connectedness，or nonlinear relationships and dynamical emergence（1998，p. 87）.

While Lemke's distinction between typological meaning and topological meaning is programmatic，the representational resources provide concrete tools for analyzing the meaning potential of different modes. For instance，it seems that in Figure 2 the resource of color in visuals imposes the commitment to classification. Furthermore，the image of arrows employs the resource of length to indicate the speed of particle movement as the semantic category of circumstance. The two resources enable the visual representation of Figure 2 to make topological meaning，which is not possible by language.

2. Meaning Making across Different Modes

The functional specialization principle is also useful to justify the multimodal nature of human communication because any single modality is partial in relation to the whole meaning repertoire. For example，despite being a most powerful and comprehensive mode of meaning，language alone is less effective to represent the topological complexities of scientific communication，and has to mingle with other semiotic choices to expand the meaning potential. The semantic orchestration across different modes can be explored from two perspectives：the synoptic perspective and the dynamic perspective.

（1）The synoptic view.

The synoptic view of meaning making across modes mainly derives from Halliday and Hasan's（1976）research on linguistic cohesion（i. e. meaning relations between linguistic expressions）. Multimodal representations are therefore regarded as one single textual phenomenon in which cohesive devices function to integrate verbal and other semiotic forms as a coherent whole. For example，drawing on the representational grammar system of visual design

and the categories of lexical cohesion，Royce suggests a range of multimodal cohesion such as inter-semiotic repetition, hyponymy and collocation to analyze text-image relations （1998，p. 29），which is useful to reveal students' conceptual difficulties in understanding academic discourse.

For instance，Crisp and Sweiry （2006） investigated multimodal phenomena in chemistry examination questions. In one of their collected sample questions，Figure 3 was accompanied by the verbal part （ [...] *some brands of toothpaste contain sodium carbonate. Three products are made when sodium carbonate reacts with hydrochloric acid. What are they*?） It was reported that an extraordinarily high proportion of the young test takers gave wrong answers such as *shampoo* and *soap*.
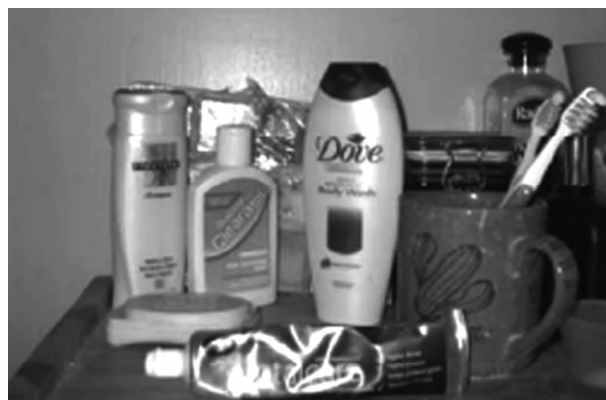

Figure 3 **Photograph in a Science Exam Question**①

According to Crisp and Sweiry，the included photograph was to blame for students' mistakes （2006，pp. 149－151）：Given that the word *products* can mean something made in a factory to be sold or something produced through a chemical process，the image showing toothpaste，shampoo and soap triggered in young learners' mind the former meaning as in *household products*. It is therefore claimed that visual images negatively affected students' understanding of scientific concepts on some occasions.

From a multimodal view，pictorial representations constitute an important modal resource to construct scientific concepts nonetheless，and

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① Figure 3 is reproduced from Crisp and Sweiry （2006，p. 149）.

should be an integral part of scientific discourse. It seems that the novice students' wrong answers may have stemmed from their lack of sufficient knowledge on multimodal cohesion.

To illustrate，when young learners strongly associated the photograph with the word "products"，they actually attempted to find the image-text meaning relation in the examination question. Considering that shampoo，soap and toothpaste were three kinds of household products，novice students thus assumed that the photograph was interrelated to the word *products* through the semantic link of hyponymy.

In contrast，the examination designer was likely to link the photograph with the word "toothpaste" through the cohesive resource of intersemiotic repetition，as the concept of toothpaste was visually represented in Figure 3，and through the cohesive device of intersemiotic collocation，for toothpaste was often put in the same place with other household products such as shampoo，soap and hand wash.

The meaning-based examination indicates that the inclusion of photographs in Figure 3 did not necessarily give rise to students' misunderstanding of the examination question. Rather，young test takers obviously realized that there existed semantic links between the visual and verbal components in a multimodal representation. The challenge for them was how to identify the type of image-text cohesion intended by the examination designer. This problem can be resolved when students learn basic knowledge about intersemiotic cohesion.

（2）The dynamic view.

While a synoptic account is useful to explore multimodal communication from a spatial perspective and effectively reveals semantic convergence between various modes，it is limited in its ability to demonstrate how meaning changes and expands in multisemiotic discourse. Complementarily，a dynamic view is needed to examine how crossmodal processes unfold through time.

Pioneering dynamic analysis of semiosis might be best represented by Iedema's（2001）*resemioticization* research，which focused on how organizational discourse progressed across different modalities in its real-time unfolding process. For example，a project of renovating and expanding a

mental hospital started with embodied semiotic resources such as spoken language，gestures，and facial expressions at planning meetings. Then it moved to disembodied resources including written planning reports and the visual architectural design，and ultimately changed into the most durable sign：the buildings.

Iedema noted that in the semiosis process，meaning was under constant changes（2001，p. 30）. For instance，the architect-planner's written summary was far from a mere reflection of what was said by the medical staff at earlier stages；instead，the architect-planner selected particular lexicogrammatical resources to semantically metonymize the stakeholders so that others would find it very difficult to challenge his utterance. In addition，when the written report was later visualized as a design，individual stakeholders' opinions and expectations were further compromised.

Likewise，Thibault re-interpreted multimodal communication from a semogenetic perspective as the ongoing contextualization of meanings arising from different modalities（2000，p. 362）. Lim classified contextualizing relations as two sub-types：co-contextualizing or convergence where the meaning of one semiotic resource shares similarity with the meaning of another，and re-contextualizing or divergence where the meaning of one modality seems to be odd with the meaning of another（2004，p. 239）.

While these pioneering studies provide programmatic accounts of general meaning making patterns in the process of resemioticization，analytical frameworks are needed to demonstrate what semantic changes take place and how the changes are realized through cross-modal modulations.

Taking a meaning-based approach，Liu and Owyong examined how the subject of chemistry was historically resemioticized from language to symbolic expressions（2011，pp. 829－832）. Based on the grammatical analysis of language and chemical symbolism，the two authors proposed several mechanisms to describe the semantic changes of resemioticization. For example，when the technical term *copper oxide* evolved as $Cu + O$ in the early 1800s，the mechanism of intersemiotic transcategorization was found to operate to expand the meaning potential of chemistry.

Grammatically，*copper oxide* is a noun and thus construes the meaning

of a thing. In contrast，$Cu + O$ is a symbolic clause in which both Cu and O function as co-equal participants to activate the process. It therefore follows that symbolic expressions of chemicals，far from a fanciful way of representing their names. On the contrary，the symbolic form implies that chemical compounds were no longer regarded as a stable entity but as a dynamic interaction between different particles at the atomic level. Such a semantic shift was crucial to support and develop the submicroscopic view of chemistry as a new theory in the early 19th century. In this sense，resemioticization enables scientists to effectively explore chemical phenomena with new research tools.

Ⅳ. Issues in Social Semiotic Multimodal Research

Taking Halliday's（1978）social interpretation of communication as the point of departure，social semiotics has been usefully adopted to theorize multimodal research and has effectively addressed a number of research questions. Despite the increasing interest in social semiotic multimodal research，some of its theoretical assumptions and analytical approaches were questioned and criticized even by social semiotic scholars in recent years. The present section comments on several raised issues and aims to clarify important points of multimodality.

1. Formulation of Modal Systems

Social semiotic multimodal research is claimed to be primarily interested in formulating inventories of the semiotic potentials as exemplified by O'Toole's（1994）articulation of systems of choice in displayed art and O'Halloran's （2005） grammatical systems for analyzing mathematical discourse. This method is questioned for its alleged partiality，because any suggested modal system cannot "map all the complex ways in which people make meaning ［...］ given the dynamic and changing character of meaning making"（Jewitt，2006，p. 19）. It is also argued that the modal systems consist of pre-determined categories and are conceived as prescriptive rather than descriptive （Jewitt，2009b，p. 30）.

The issue of partiality in the account of modal systems can be addressed

by applying the key notion of "instantiation" in social semiotics that system and text lie at the poles of the same cline. As Knox aptly states，the foundational work of O'Toole（1994）attempts to map out the meaning potential of displayed art and is located near the axis of system（2009，p. 130）. Since a system is essentially characterized by abstraction and generalizability，it need not "*fit the instance in its specificity as it occurs in nature*"（Cartwright，as cited in Hasan，1995，p. 188，italics in original）.

However，this does not entail that social semiotic multimodal studies pay little attention to the "instance" pole of the cline. For example，O'Toole's（1994）systemic grammars of buildings have inspired multimodal research including the semiotic make up of an exhibition at the Singapore History Museum（Pang，2004）and of Singapore's Orchard Road and Marriot Hotel（Alias，2004）. Analysis of these specific instances not only provides a testimony to the applicability of O'Toole's（1994）grammatical framework，it also provides feedback for the original systems. [①]

Furthermore，the networks and categories of the modal systems do not make prescriptions，but offer meta-knowledge to conceptualize semiotic artifacts and activities and make an explicit account of their meaning potential. For instance，the system of *transitivity* in language has been extended to investigate multimodal discourse（see Figure 1）. As Kress and van Leeuwen note，they do not simply impose linguistic terms on visual design（1996，p. 76），for instance，to identify a "visual material process"（though there are parallels when language and images construe the experience of "doing"）. Rather，the *transitivity* system provides a productive analytical tool to model meaning-making patterns in visual images and other semiotic resources.

Admittedly，the validity of the proposed modal systems even in the foundational work of Kress and van Leeuwen（1996）and O'Toole（1994）need to be further testified and recent multimodal research exercises more caution when adopting these analytical frameworks. For example，when

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① For example，Alias（2004）discusses how the grammar of buildings contributes to the construction of capitalism and consumerism and thus extends O'Toole's（1994）grammatical analysis of displayed art to the more abstract semiotic level of ideology.

analyzing multisemiotic print documents，Bateman questions the feasibility of Kress and van Leeuwen's（1996）ideological interpretation of the compositional system of *information value*（2008，pp. 40－53）.

Likewise，Jones' empirically grounded analysis of science textbooks reveals that images and verbal texts can appear on either the left-hand or right-hand side of the page（2007，pp. 249－250），which provides counter evidence of Kress and van Leeuwen's（1996）claim that the horizontal axis of a page carries the *information value* of Given-New where linguistic components frequently occupy the left-hand side to present something the reader is familiar with while the right-hand side is often taken by visual displays to convey contestable information. However，the new strand of empirical research does not invalidate the whole proposed modal systems，but provides revisions to the model.

2. Stratification of the Content Plane of Multimodal Discourse

From a meaning-based view，language is a multistrata semiotic system，which construes，is construed by，and over time re-construes context. In a similar vein，other modalities operate in the semiotic environment of context，and are stratified into the content plane and the expression plane（Matthiessen，2009，p. 12）. However，it remains an issue whether the content plane of non-verbal forms of semiosis can be split into the strata of semantics and grammar.

Firstly，it is found that some modalities（e. g. mathematical symbolism）historically had a linguistic origin，and thus were highly similar to language in terms of the semiotic organization patterns（O'Halloran，2005，pp. 94－97）. Furthermore，while other modes such as visual displays possess quite different meaning potential from language，preliminary stratified models（e. g. O'Halloran，2005，2008；Lim，2004）have been usefully applied to demonstrate multimodal meaning making in mathematical discourse，print advertisements and children's picture books.

Closely related is another question whether the notion of rank，which is originally used to analyze the grammar of language，is also productive to map out the meaning potential of multimodal discourse（Machin，2009，pp. 186－

188）．Martinec explains that it is determined by the size and nature of the analytical data whether images should be modeled according to ranks（2005，pp. 162-163）．For instance，O'Toole's（1994）examples such as Botticelli's *Primavera* belong to large-scale narrative events consisting of diverse episodes of more or less equal status．In contrast，Kress and van Leeuwen（1996）select less complex narrative images with one main process in which the notion of rank is less important for analytical purposes．

Taking Martinec's（2005）argument as the point of departure，it seems that the feasibility of internal stratification and ranks of multimodal representations relies on the nature of the contexts in which they are used．For instance，the two notions are crucial in the analysis of scientific discourse．Firstly，mathematical and chemical symbolism grew out of natural language and develops similar patterns of semiotic organization．Also，scientific diagrams historically developed unique grammatical resources，and a rank-based account was productively used to shed light on how sophisticated scientific knowledge is constructed（Liu & DwiNugroho，2012）．

3．Inadequate Emphasis on Context

Social semiotic multimodal research is also criticized for being pre-occupied with building grammatical inventories at the cost of contextual analysis．According to Machin，while O'Toole is firmly against the knowledge "that can be read up in a library"，his analysis of *Primavera* actually relies on contextual knowledge rather than the application of the visual grammar（2009，p. 187）．However，it should be kept in mind that O'Toole（1994）never emphasizes grammar over contextual knowledge；his argument is that contextual knowledge *alone* is limited in its ability to take the meaning of semiotic artifacts and needs to be implemented with a grammatical analysis．

Despite O'Toole's（1994）focus on building inventories of the semiotic potentials，his main purpose is to lay the foundation for the grammatical approach to multimodal discourse．In fact，from a social semiotic perspective，grammar is the essential resource that construes experience （Halliday & Matthiessen，1999，p. 17）．So it might not be appropriate to

conclude that O'Toole (1994) pays little attention to context just because of his account of grammaticality.

A comparable example is Halliday and Matthiessen's（2004）*An Introduction to Functional Grammar*，which makes a comprehensive account of grammatical resources in language rather than of social context. Obviously，this book does not count as evidence that Halliday and Matthiessen tend to ignore the notion of social context. It is worth mentioning that the proposed grammatical frameworks are not the whole story of multimodal research，but a starting point to analyze multimodal discourse and allow readers/viewers to relate the analysis to "the social，intellectual，and economic world within the artist and his patrons worked"（O'Toole，1994，p. 4）.

In fact，much of existing social semiotic multimodal research makes in-depth analysis of social context. To take an example，O'Halloran（2009）investigates the historical evolution of mathematical discourse and explores how social and technological changes shape the semiotic landscape of mathematics. Furthermore，taking Bernstein's sociology of education，O'Halloran's（2005）analysis of mathematics classroom discourse is not limited to the situated interaction between teacher and students under observation，but takes into account the curriculum and the underlying socio-cultural relations.

4. Redundant Terminology

In order to map out the meaning-making systems of different semiotic resources and cross-modal interaction，social semiotic research develops a meta-language to describe grammars and functionality of multimodal discourse. The meta-language entails the use of terminology，which has incurred criticisms that social semiotics tends to multiply the terms in use and create semiotic entities (Machin，2009，p. 189).

The first point to be clarified is that multimodal social semiotic approaches do borrow existing technical terms from other fields of research. One example is the crucial notion *modal affordance* in multimodality. As Jewitt points out，the term *affordance* originated in Gibson's cognitive

theory and was interpreted as a matter of perception（2006，pp. 25－26）. However，when applied in multimodal studies，*affordance* is no longer a psychological concept but a complex one involving the material and the socio-cultural aspects of semiotic resources（Jewitt，2009b，p. 24）.

Secondly，given that social semiotics is a specialized field and its experiential meaning is realized in the patterns of lexis，it is not only necessary but also important for multimodal research to develop its own terminology（Wignell，Martin，& Eggins，1993，p. 162）. For instance，when analyzing the generic structure potential of print advertisements，Cheong（2004）coins the technical lexis *lead* to describe the most outstanding visual component. It should be kept in mind that *lead* is far from redundant or a fanciful way of saying the image. Instead，this notion is meaning-oriented and emphasizes the interpersonal metafunction of visual displays in the advertisement.

In the mean time，social semiotic scholars（e. g.，Bezemer & Kress，2008；Jewitt，2009a，2009b；O'Halloran，2005）have made preliminary efforts to clarify crucial terminology in multimodal studies such as *semiotic resource*，*mode*，*modality*，*multimodal* and *multisemiotic* to avoid potential misunderstanding.

Ⅴ. **Pedagogical Implications and Concluding Remarks**

In the past few years，the meaning-based approach to multimodality has well informed research in a wide range of disciplines，notably in the field of science teaching and learning.

Firstly，social semiotic multimodal research is epistemologically significant for science education. The semantic analysis of multisemiotic phenomena in scientific discourse reveals that scientific concepts are constructed in representational forms and constantly shaped and re-shaped by lingual，visual，symbolic and many other modal resources. It therefore provides further evidence to support the view that "knowledge is seen，not as a resolved set of declarative concepts，but as a network of interlocking representations that are to some extent negotiable and 'in process'" (Hubber，Tytler，& Haslam，2010，p. 19).

Secondly，social semiotic theories also provide a meta-language for teachers and learners to negotiate the meaning of scientific representations. While the use of a meta-language is sometimes criticized as a weak point of multimodal research，the New London Group argues that an accessible social semiotic meta-language is much needed to facilitate a rise in literacy，because the meta-language can provide an explicit account of the link between the modal systems and their use in social contexts (1996，p. 77).

Despite the concern over the technical aspects of the meta-language，recent studies in primary and secondary schools provide preliminary evidence that even young pupils can learn the basics of social semiotics，and the meta-language does not lesson students' enjoyment，but enhances the their engagement with the pedagogical discourse，develops their critical orientation，and improves their learning outcomes (Unsworth，2008).

As may be clear from the preceding discussion，this research aims to contribute to two different communities. By describing the research scope of multimodality，the present study calls for educational researchers and practitioners' attention to semiotic complexity in scientific discourse and offers them a meaning-based approach to examine how scientific knowledge is constructed in the form of single and multiple modes. Also，this study responds to several criticisms semiotics scholars made of social semiotic multimodal research and attempts to clarify some of the theoretical and methodological issues. However，further research is needed to theorize multimodality and engage with its limitations.

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