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LOGGERS AND CONSERVATIONISTS

Navigating the Multiple Resource Forest through the Trees

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ABSTRACT

In this introduction to the *Handbook of Learning from Multiple Representations and Perspectives* we use the metaphor of “seeing the forest through the trees” to conceptualize the nature of multiple resource learning. First, in comparing resources to trees, we identify these as originating from sources (i.e., roots), including specific content (i.e., trunk), and taking on various representational formats (i.e., leaves). Second, we identify the cognitive processes involved when learners conceptualize individual resources (i.e., trees) and identifying the connections among them for holistic understanding (i.e., see the forest). Finally, we suggest that learners may be viewed as loggers and conservationists seeking to take advantage of the resources available within a multi-resource forest and to understand the complex ecosystems within it.

Key words: multiple representations, multiple perspectives, multiple resource learning

At the dawn of the Internet Age, Elm and Woods (1985) described a phenomenon of *getting lost*, wherein a learner “does not have a clear conception of relationships within the system, does not know his present location in the system ... and finds it difficult to decide where to look next within the system” (p. 927). Elm and Woods’ lost learner may be described as having trouble navigating the dense forest of information through the trees, a problem that has, if anything, become more pronounced with the growing predominance of the Internet (Amadiou, Tricot, & Mariné, 2009; DeStefano & LeFevre, 2007). The ubiquity of the Internet and other technological developments mean not only that learners are inundated with an ever-expanding torrent of information, but that this information is both diverse and complex. Learners now encounter information mediums beyond text, including images and videos, with new formats introduced every day (e.g., infographics, gifs, emojis). Beyond these formatting differences, the information available on the Internet today is heterogenous. Gone is the age of editorial discretion and information gatekeeping (Coiro, 2003; Marchi, 2012; Metzger & Flanagan, 2013). Instead, today’s learner encounters not only information that was created to inform and persuade but also to misdirect, mislead, and deceive (Lazer et al., 2018; List & Rubenstein, 2019; Tandoc, Lim, & Ling, 2018). Learners today need help making sense of the wealth and diversity of information on and offline. We conceived of this *Handbook* as an effort to do just that. We aim to help learners traverse the dense forest of information by integrating two independently unfolding lines of research – those of learning from multiple representations and from multiple perspectives. Learning from multiple representations occurs when individuals try to make sense of information presented across multiple, separable representations that differ in symbol systems, formats, or modalities (e.g., texts, diagrams, formulas), with separate representations typically providing content that is consistent and overlapping but not entirely redundant. Learning from multiple perspectives occurs when learners try to understand complex or controversial issues; such issues are often defined by there being a variety of viewpoints, requiring the juxtaposition and integration of these perspectives for learning. We believe that, although developing separately, these lines of research jointly capture the challenges inherent in learning in the 21st-century knowledge society – challenges associated with not only the volume of information available, but also its mixed modality, its potentially indeterminate or inexplicit origin and positionality, and its implicit inter-relatedness to a wealth of other multimodal, ambiguously sourced content.

We introduce the factors and mechanisms associated with learning from multiple representations (Section 1) and from multiple perspectives (Section 2) as well as the characteristics and skills that learners need to be successful at each pursuit (Section 3) and the challenges and opportunities that they may encounter (Section 4). We close this *Handbook* by introducing a framework, the Multiple Resource Learning Framework that, for the first time, explicitly links the learner characteristics and processes jointly involved in learning from both multiple representations and multiple perspectives, the contexts, tasks, and resources that shape such learning, and the constructions that are developed as a result. To foreground this ambitious pursuit, we use the expression of *seeing the forest through the trees* to conceptualize the fundamental goal that learners must accomplish when learning from information resources featuring multiple representations and multiple perspectives. Using this metaphor, we describe how (a) any multimodal and/or multi-positional information resource may

be thought of as a tree, (b) how such trees may figure into a broader sylvan landscape of information, and (c) how learners may be conceptualized as loggers and conservationists trying to exploit and cultivate thorny thickets of information on their own and with various degrees of instructional support. We close this introduction with an overview of each *Handbook* section.

INFORMATION RESOURCES ARE LIKE A TREE

Trees have three main parts – the roots, the trunk, and the leaves. So too can information resources be described as having three main features: source, content, and representational format (List & Alexander, 2018). *Source* refers to accessible information about a resource’s origin or purpose for being created, including information about author and publisher (Bråten, Strømsø, & Britt, 2009). In addition to serving as a basis for determining trustworthiness, the source contributes to the *perspective* of a resource. In this *Handbook* we define perspective as the collection of attitudes, values, beliefs, knowledge propositions, and goals that guide the presentation of information, including decisions about what content to focus on and which to exclude and which representational format(s) to use in what ways. These attitudes, values, beliefs, knowledge propositions, and goals may be expected to proceed from the author of a given resource, as well as the author’s social, cultural, and epistemic (i.e., domain) communities. Nevertheless, while the bulk of prior work, particularly in the field of learning from multiple texts, has focused on understanding learners’ determinations of source benevolence and expertise (Bråten et al., 2009; Stadtler & Bromme, 2014), we chose, in this *Handbook*, to focus on a source’s perspective(s). Perspective, in addition to linking individual authors to broader sociocultural and epistemic communities (e.g., domains), also links author’s positionality with their decisions around what content to include and what representational formats to feature in presenting information to an audience. For instance, similarly benevolent and expert authors may choose to include quotes or narrative descriptions as evidence vis-à-vis data tables and statistical analyses, depending on their epistemic and methodical perspective(s). Similarly, whether authors support or oppose a given proposal may be more a question of perspective than of expertise.

We view the different perspective(s) that authors hold and reproduce in the resources that they create as roots of a tree. Like roots, these perspectives are mostly hidden, rather than manifest, and uncovering these roots is oftentimes an effortful and deliberate process, as demonstrated by the literature on sourcing within the context of learning from multiple texts (Brante & Strømsø, 2018; Britt & Aglinskias, 2002; Strømsø & Bråten, 2014). Nevertheless, their covert nature makes roots or author’s perspective no less foundational to the content and representational format of particular resources or trees of information.

We liken a resource’s informational *content* to the trunk of a tree, constituting its substantive essence or core. Leaves, then, are the *representational format(s)* that particular resources take on. We use the term representational format to indicate the modalities or symbol system(s) encoding information within particular resources as well as the particular formatting of these systems. While the two primary modalities examined in prior work have been the visual and the linguistic (Mayer, 2001; Mayer & Anderson, 1992), symbol systems as varied as graphic representations, algebraic

expressions, and musical notation all constitute different types of representational formats (Loughlin, Grossnickle, Dinsmore, & Alexander, 2015). In this *Handbook* and in the literature on learning from multiple representations, more broadly, our concern is primarily with informational materials that include within them more than one representational format (i.e., multimedia). Such materials characterize the vast majority of information that learners may be expected to encounter, across a range of educational contexts, including when learning using textbooks or the Internet. We do not consider a resource's representational format(s) to be a superficial matter of style, rather, we view these as a deliberate, perspective-driven choices on the part of authors (Schnotz & Baadte, 2015; Schnotz & Bannert, 2003). We further acknowledge that it is oftentimes the representational format that may suggest to learners the starkest contrasts among resources. That is, learners may much more readily perceive differences among texts, diagrams, and animations, even if these are representing the same content, than they would more subtle contrasts between authors holding different perspectives on a common issue. This is similar to how we perceive the differences among pines, oaks, and palms most starkly because of their leaves, despite these also varying in qualities of their roots and trunk.

To extend this metaphor further, source perspectives, content, and representational formats are inextricably linked as are roots, trunk, and leaves. Likewise, just as the nature of trees' roots, trunk, and leaves represent an environmental adaptation, so too can information resources be viewed as derived from and existing within their sociocultural and epistemic contexts. As an illustration, consider that the content and representational format characteristics of journal articles within any scholarly domain are a result not only of author perspective but also of the historical legacies and conventions of academic publishing. Likewise, the content of Tweets and any hashtags assigned are both a matter of author perspective and of Twitter communities' communicative practices.

As a final note, the term informational resource, or input, is used with intention both in this introduction and throughout this *Handbook*. Resources and inputs are broad terms that encapsulate the multitude of sources, texts, perspectives, and representations that learners may be expected to encounter during complex learning tasks, as reflected in the literatures on learning from multiple representations and from multiple perspectives. Moreover, resources hold a dual meaning as scaffolds provided to aid learners and as materials needed to be effortfully extracted and manufactured before they can be used. We consider these dual meanings to be particularly apt for capturing how resources are viewed in the fields of learning from multiple representations and from multiple perspectives. On the one hand, particularly in the literature on learning from multiple representations, resources are deliberately designed by teachers and researchers to aid learners in the process of learning. Indeed, color codes, in-text deictic references, labels, and other signaling devices (Lorch, Lemarié, & Grant, 2011; Scheiter & Eitel, 2015) have all been used as means of modifying multimodal instructional materials to be more accessible and effective resources for learners (Richter, Scheiter, & Eitel, 2016). On the other hand, both the literatures on learning from multiple perspectives and multiple representations recognize that learning from even the most optimally designed instructional resources is not an automatic or passive process for learners. Rather, these literatures approach learning as an active, deliberate, effortful, and strategic process. In the section that follows,

we highlight some of the strategic processes that may be expected to be involved in individuals' learning from multimodal and multi-perspective resources. We frame these processes as those required to conceptualize the information forest through the various multimodal and multi-perspective trees.

MULTIPLE, MULTIMODAL, MULTI-PERSPECTIVE RESOURCES ARE LIKE TREES IN A FOREST

In the previous section, we established that trees constitute a potent metaphor to capture the source perspective, content, and representational format(s) that define any informational resource. In this section, we move from considering informational resources or trees in isolation to viewing these as part of a dense informational forest. Indeed, making sense of trees or informational sources in relation to one another may be the fundamental task inherent in learning from multiple representations and multiple perspective, or in seeing the forest through the trees. We consider such relational sense making to be guided by three features of multi-resource learning tasks.

First, multi-resource learning tasks require that each resource included be understood individually, as itself. That is, in order to form relations across information resources, each resource must be understood both holistically and analytically. This requires both understanding a given tree as a whole and decomposing the sub-components within it and identifying the relations among these parts. We see such holistic and analytic comprehension processes manifest in both the literatures on learning from multiple representations and from multiple perspectives. In the literature on learning from multiple representations, it is common to analyze learners' distribution of attentional resources (e.g., gaze patterns) across individual representational components within a multimedia resource (e.g., a text and a diagram) and as shifting between these (Mason, Pluchino, Tornatora, & Ariasi, 2013; Ozcelik, Arslan-Ari, & Cagiltay, 2010). Likewise, the emergent literature on learning from multiple perspectives, stemming largely from the literature on learning from multiple texts, has focused on learners' mastery of outcomes associated with both comprehension and integration; while the former has been concerned with learners' understanding of individual texts and the perspectives provided within them, the latter has been concerned with learners' cross-perspective and cross-text relation formation across the resources available (Florit, Cain, & Mason, 2019; Gil, Bråten, Vidal-Abarca, & Strømsø, 2010; List, Lee, & Du, under review).

Second, as suggested by the examples above, multiple resource learning is fundamentally an exercise in relation formation within and across multimedia resources. We see this relation formation evidenced both when learners link multimedia features within a single resource and when learners identify complementary, corroborative, causal, and conflicting relations across a set of resources provided (Ainsworth, 2006; Braasch, Bråten, Britt, Steffens, & Strømsø, 2014; Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; List, Du, Wang, & Lee, 2019; Wiley et al., 2009). Here the metaphor of seeing the forest through the trees becomes even more potent. For there to be a forest, trees of various types need to be presented alongside one another. But it is not the physical positioning of trees side by side that makes up a forest; rather, the forest is an ecosystem with trees inter-related to one another in a variety of sophisticated ways. Symbiosis, mutualism, commensalism, parasitism, competition, and predation

all describe relationships in the forest ecosystem. Yet these relationships are not readily apparent nor easily seen and thus uncovering these delicate interconnections requires deliberate analysis. Similarly, the relationships among multiple, multimedia resources are often complex and opaque so that learners must engage in careful analysis and construction in order to identify the relationships among these. These challenges may, in part, be a consequence of the nature of the relationships between resources, such as when perspectives disagree with, dispute, or discredit one another or when two representations serve different functional roles.

Finally, it is critical to recognize that seeing the forest through the trees is fundamentally a matter of perspective. Wandering through the forest allows for comparing trees to one another, but it is only by standing at its edge or flying above it that a forest could possibly be conceptualized in its entirety. This reminds us, first, that learners are not neutral observers; rather, it is their positionality within the forest that dictates what trees they see, how they perceive these, and their ability to discern the connections among these. This conclusion is well supported by literature indicating that how learners engage with multiple representations and multiple perspectives is influenced by a host of unique individual differences, including learners' own attitudes, perspectives, prior knowledge, and cognitive abilities (Kardash & Scholes, 1996; Lord, Ross, & Lepper, 1979; Rau, 2018; Taber & Lodge, 2006; Van Meter, Cameron, & Waters, 2017). At the same time, pragmatically, an entire forest, in its totality, can rarely, if ever, be seen, especially as its boundaries and constituencies are constantly in flux. Instead, learners are much more likely to study an area or a patch of land, as a proxy for the broader forest beyond. Such study requires the simultaneous recognition that the forest is a boundless information landscape and that we have limited capabilities to process or understand it all. This tension between information volume and individuals' limited processing capacities may be at the heart of the difficulties associated with learning from multiple resources and the driving force behind Elm and Woods' (1985) conceptualization of being lost.

The vastness of the information available and our correspondingly limited processing capacities are only some of the challenges associated with learning from multiple representations and from multiple perspectives. A forest represents a foreboding landscape not only because of the volume of trees within it or their varied nature but also because a forest represents a profound unknown, equally likely to contain trails that guide the way through and those that meander in circles. So too, in understanding learning from multiple representations and from multiple perspectives it is necessary to recognize that at least some of the challenges associated with learning from such resources come from learners approaching these with, definitionally, little knowledge of the information within them. Learners do not know the possible connections that could exist across representations or the range of perspectives that there may be on a given topic. To address this gap requires explicitly signaling connections across multimedia representations and using graphic organizers and other scaffolds to systematize and connect the perspectives that learners are likely to encounter. Although the former has extensively been done in the field of learning from multiple representations (Mayer, 2001; Richter et al., 2016), the latter is only now being introduced within the literature on learning from multiple perspectives (Barzilai & Eshet-Alkalai, 2015; Kiili & Leu, 2019; Luo & Kiewra, 2019).

The limited knowledge that learners may bring to bear on learning from multiple representations and multiple perspectives may be mitigated by effectively designing instructional resources, like clearly marked hiking trails through a forest. Nevertheless, a final aspect of viewing today's informational milieu as a forest landscape is recognizing that most of the journeys that learners are likely to take will not follow such well-worn trails. Learners instead are likely to wander along winding paths, some of which may leave them more lost than when they started. This describes the nature of learners' information use in the era of virality, truth decay, and deep fakes, all occurring alongside the decline of traditional notions of reliability and expertise (Kendeou, McCrudden, & Robinson, in press; Mills, 2012; Shao et al., 2018). It is for this type of wandering that we aim to equip learners through this *Handbook*. It is our hope that teaching learners to traverse the information forest more strategically will help them to better take advantage of the abundances within it.

LEARNERS AS LOGGERS AND CONSERVATIONISTS IN AN INFORMATION FOREST

While recognizing the challenges facing learners seeking to traverse the multi-resources forest, it is also the case that learners can, indeed, overcome such challenges. Extending our metaphor of the information forest, we suggest that learners may do so by adopting the roles of loggers or conservationists.

Loggers adopt a utility-focused approach to multiple resource use. While intimately familiar with the characteristics of different types of trees, they are ultimately focused on converting trees into logs of a fairly uniform and standard size. This parallels the focus on problem solving and application and transfer widely emphasized in the literature on learning from multiple representations (Brenner et al., 1997; Lesh, Post, & Behr, 1987; Schönborn & Bögeholz, 2009). Information users who are loggers deal with the complexity offered by the multitude of multimodal and multi-perspective resources available in the information forest by focusing on homogenization. That is, just as loggers seek to mitigate the complexity inherent in working with trees of many different shapes and sizes by stripping away the leaves and bark to create logs of uniform width and height, so too learners working with multiple resources select key information across resources and identify points of commonality across them in an effort to reduce information variety and volume. This process of reduction and coordination may be considered to be central to the logger approach to information use, as is the adoption of utility-focused goals.

Conservationists utilize a somewhat different approach. Although no less active in their engagement with information, conservationists are much more reflective in their resource use. Conservationists are concerned with understanding trees, the relationships among them, and the broader ecosystem. While deeply engaged in understanding and analyzing the information forest, in contrast to loggers, conservationists are less inclined to make bold use of the resources available. This parallels work on learning from multiple perspectives, which has thus far emphasized learners' comprehension and integration of multiple perspectives, but less so their use of multiple perspectives to solve problems or to develop perspectives of their own. Crucially, a key feature of the conservationist approach is its concern with sustainability and tree health, paralleling evaluative and epistemic considerations much emphasized in

the literature on learning from multiple perspectives (Kohnen & Mertens, 2019; Stahl, Hynd, Britton, & McNish, 1996; Strømsø, Bråten, & Samuelstuen, 2003).

While loggers were described as managing information volume and resource complexity by engaging in selection and harmonization, conservationists are more inclined to appreciate, analyze, and seek to find patterns in, but not necessarily strive to reduce, information complexity. These learners may deal with the variability of resources populating an information forest by seeking to understand and systematize this variability, but not necessarily to eliminate or reduce it. Moreover, conservationists may be said to be less utility-focused in their multiple resource use, as compared to their logger counterparts. Rather, conservationist learners may be expected to be more academically oriented, viewing information resources and perspectives more intellectually as objects of inquiry, rather than only as resources to be used to accomplish some goal.

Of course, not all learners may be loggers or conservationists, both metaphors defined by the adoption of an active approach to resource use. Some learners may simply be survivalist. These learners, even when thrust into an information forest, may seek to limit their engagement within it and hope only to emerge on the other side, unscathed. Such survivalist orientations are demonstrated in the literature on learning from multiple representations in learners' tendencies to rely on text-driven processing even in the presence of additional visual representations (Bartholomé & Bromme, 2009; Mason, Pluchino, & Tornatora, 2015) and in the literature on learning from multiple perspectives in some learners' reluctant or deliberately limited information use (Lawless & Kulikowich, 1996; List & Alexander, 2017). In contrast to loggers and conservationists, these learners are unlikely to view the information forest as one of resource abundance. Rather, such learners may be profoundly aware of the perils of the information forest and to acutely fear "getting lost" within it. It is, in part, these learners that we seek to aid with this *Handbook*; learners wandering lost in the information forest or reluctant to proceed within it. That is, by integrating the literatures on learning from multiple representations and from multiple perspectives we hope to map the challenges presented by the multiple resource forest and to identify the trails and tools necessary to traverse these.

Sfard (1998), in presenting acquisition and participation as two different metaphors for learning, explicitly cautions about the dangers of relying on a single one. She writes:

the relative advantages of each of the two metaphors make it difficult to give up either of them: Each has something to offer that the other cannot provide. Moreover, relinquishing either ... may have grave consequences, whereas metaphorical pluralism embraces a promise of a better research and a more satisfactory practice.

(p. 10)

Within this *Handbook* we wholeheartedly embrace Sfard's (1998) proposition. Learners need to be taught to be both loggers and conservationists; to understand, evaluate, make use of, and integrate the resources that are abundant in the information forest, but are oftentimes quite difficult to grasp. That is, like loggers, learners must be taught to make efficient use of the resources available to solve problems; and, like conservationists, learners ought to be taught to engage with resources in an analytic

and evaluative fashion – construing resources relationally and on an author’s terms. As is the case for both loggers and conservationists, learners’ development in these regards can only come from deliberate experiences engaging with diverse information resources in a variety of ways. These types of experiences are what future classrooms in the information age should afford.

The metaphors we offer throughout this chapter are obviously simplistic and woefully incomplete. Nevertheless, we use these to introduce the reader to subsequent discussions throughout this *Handbook* on learning from multiple representations and from multiple perspectives in an increasingly complex world. In the section that follows we introduce each section of the *Handbook* as cairns to guide the reader through.

HANDBOOK SECTIONS

Section 1 is focused on learning from multiple representations. Rau (Chapter 2) reviews theoretical frameworks for conceptualizing multiple representation learning. This chapter provides a broad view that encompasses both individuals’ cognitive operations and disciplinary practices. Kozma (Chapter 2) examines expert–novice differences in the use of representations. This chapter considers multiple representations in the context of disciplinary practices and illuminates learners’ developing abilities. Chapters in the middle half of this section focus on learning from multiple representations. The chapter by Schüler (Chapter 4) presents three different methodological approaches to uncovering the cognitive processes of multiple representations learning and reviews the findings from each. Cromley (Chapter 5) examines individual differences that are associated with multiple representations learning and examines the influence of these individual differences across tasks (e.g., fact recall, transfer) used in multiple representations research. Van Meter and Stepanik’s chapter (Chapter 6) examines interventions designed to support multiple representations learning. Dividing these according to how the intervention supports the cognitive operations of multiple representations learning, this chapter reviews materials-, prompts-, and learner-driven interventions. The final two chapters of this section expand the notion of learning from multiple representations by considering representation construction. Ainsworth, Tytler, and Prain’s (Chapter 7) focus is on learners’ construction of their own science representations and the role of these construction processes in learning. Stylianou (Chapter 8) writes about how learners use representations to aid mathematics problem solving. Together, these final two chapters paint a picture of active learners engaged with representations in generative ways.

Section 2 is focused on learning from multiple perspectives. The section begins with a chapter by Barzilai and Weinstock defining what constitutes a *perspective*, particularly in light of prior work on the role of author or source in individuals’ learning from multiple texts. Then, three chapters in this section focus on the individual difference factors involved in learning from multiple perspectives. These include a chapter by Bråten and Strømsø (Chapter 10) focusing on learners’ epistemic and ontic beliefs; a chapter by List (Chapter 11) focusing on the role of learners’ emergent domain understanding in multiple perspective learning; and a chapter by McCrudden (Chapter 12) examining how learners’ attitudes and beliefs may be reflected in the perspectives that they themselves adopt when processing perspective-consistent and -inconsistent information. The next set of chapters focuses on the processes involved

in individuals' learning from multiple perspectives. These include examinations of learning from both complementary (Firetto, Chapter 14) and conflicting (Braasch & Scharrer, Chapter 13) perspectives and validation and evaluation processes that are common to learning from multiple perspectives, related to one another in a variety of ways (Richter, Maier, & Münchow, Chapter 16). Finally, the last chapters in this section address how instructional materials and classroom tasks may be used to facilitate learning from multiple perspectives. These chapters include Bohn-Gettler (Chapter 15) discussing how different types of texts may be modified to foster learners' multiple perspective learning and Cho, Kucan, and Rainey (Chapter 17) demonstrating how multiple perspective learning may be fostered through historical inquiry tasks in the social studies classroom.

Section 3 draws on the major constructs and theories populating the educational psychology landscape to explore how such theories conceptualize the integration of multiple perspectives and multiple representations for learning. Follmer and Sperling (Chapter 18) discuss and delineate how executive functions can serve a key role and shape learning during the integration of multiple representations and multiple perspectives. Denton, Muis, Munzar, and Etoubashi (Chapter 19) examine how learners can use self-regulated learning and metacognitive strategies to make sense of multiple representations and multiple perspectives. Lombardi, Heddy, and Matewos (Chapter 20) propose a model suggesting that multiple representations and multiple perspectives mediate the relations between values, attitudes, and beliefs in learning situations. Similarly, Miele, Nokes-Malach, & May (Chapter 21) provide a motivational model of integrative processing, which identifies factors that may influence learners' motivation when integrating various types of representations and perspectives. Pekrun and Loderer (Chapter 22) review theories that inform our understanding of emotions present in learning situations and break down how multiple representations can guide learners' emotion-prompting appraisals and contrary perspectives can foster emotions that influence the processes and outcomes of learning. Alexander and the Disciplined Reading and Learning Research Laboratory (Chapter 23) make the argument that relational reasoning is a critical cognitive capability to facilitate learning from multiple representations and multiple perspectives. Cartiff and Greene (Chapter 24) conclude the section by providing a discussion of how theoretical and empirical work reveals ways that multiple representations and multiple perspectives can facilitate learning, particularly when learners are adept critical thinkers.

Section 4 is focused on the challenges and opportunities that learners encounter in the context of learning from multiple representations and multiple perspectives. The first three chapters in this section discuss the challenges posed by the ever increasing and unregulated information ecosystem that includes multiple representations and multiple perspectives, while also making distinctions between knowledge, misinformation, and fake news. Rapp, Donovan, and Salovich (Chapter 25) revisit an old problem, that of the nature of knowledge, and discuss the challenges that emerge as a result of different conceptualizations of knowledge representations: facts and constellations. Sanderson and Ecker (Chapter 26) focus on the challenge of misinformation, our susceptibility to it, and ways to reduce it. Kendeou, Harsch, Butterfuss, Aubele, and Kim (Chapter 27) discuss the challenges that fake news pose to our intellectual survival, and how human- and technology-level solutions can be applied in the context of the information ecosystem. The next two chapters look at how multiple representations

and perspectives can be leveraged to optimize learning. Morgan, Hogan, Hampton, Lippert, and Graesser (Chapter 28) discuss how multiple representations can be integrated into intelligent tutoring systems in an effort to personalize and optimize individuals' learning experiences. Chen and Lin (Chapter 29) examine how multiple learners learn together and illustrate the ways in which multiple representations mitigate challenges and harness multiple perspectives of learners to surpass their individual understanding. In the final chapter, Azevedo and Taub (Chapter 30) discuss how measuring learners' processes and outcomes while using multiple representations can be accomplished using multimodal multichannel data.

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