Learning and Instruction 58 (2018) 137–147

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Learners' epistemic criteria and strategies for evaluating scientific visual representations

Sarit Barzilai*, Billie Eilam

Department of Learning, Instruction, and Teacher Education, Faculty of Education, University of Haifa, Israel

ARTICLE INFO

Keywords:
Epistemic thinking
Epistemic criteria
Epistemic strategies
Visual representations
Information source evaluation

ABSTRACT

Visual information sources are increasingly available online, yet little is known about how learners evaluate such information sources. Hence, the purpose of this study was to document learners' epistemic criteria and strategies for evaluating scientific visual representations (VRs). Junior high-school students evaluated four pairs of VRs that included different representations of the same phenomenon, justified their judgements, and described their criteria and strategies for evaluating good scientific VRs. Learners described and applied criteria related to the representation of the referent, to communicative quality, and to affordances for achieving epistemic aims, such as understanding. Learners applied criteria adaptively: Design contrasts between VRs evoked greater use of communicative and epistemic aim affordance criteria, whereas informational contrasts evoked greater use of representational criteria. Learners described a range of VR evaluation strategies. However, only a minority mentioned information validity and source trustworthiness evaluation strategies. Implications regarding learners' epistemic competence for evaluating VRs are discussed.

1. Introduction

Recent calls underscore the importance of fostering learners' competence for evaluating diverse information sources (e.g., Britt, Richter, & Rouet, 2014; Bromme & Goldman, 2014). Indeed, considerable empirical attention has been devoted to identifying learners' criteria for selecting and evaluating information sources (e.g., Barzilai & Zohar, 2012; Coiro, Coscarelli, Maykel, & Forzani, 2015; List, Grossnickle, & Alexander, 2015; Macedo-Rouet, Braasch, Britt, & Rouet, 2013). These studies have so far focused predominantly on evaluation of textual information sources. However, although texts retain their importance as a medium for conveying information, visual information sources are increasingly available and accessible to learners (Hegarty, 2011). For example, online information sources often include embedded images, image search engines facilitate access to images on almost every topic, and image sharing networks have turned image sharing into a popular form of communication. This creates new opportunities for learners to independently access and use visual representations (VRs) on many educational topics, particularly scientific ones. However, although we have learned much about the ways in which learners process and comprehend VRs (Mayer, 2014), we still know very little about how they evaluate and select VRs.

VRs have several features that distinguish them from verbal representations and that might influence their evaluation. Verbal and visual representations convey information through different symbolic systems (Salomon, 1979). Texts use abstract symbols (e.g., words) that are arbitrarily or conventionally related to the referent, whereas images may employ both abstract symbols and iconic signs that depict the referent by representing its structural characteristics (Schnotz & Bannert, 2003). The perceived similarity of VRs to mental images of their referents can create impressions of representativeness that may influence perceived credibility (Salomon, 1979). Furthermore, texts are arranged linearly according to a language's grammar and are interpreted linearly, whereas visual representations are arranged spatially according to representational norms and conventions, are perceived comprehensively, and are interpreted spatially (Eilam, 2012; Kress & Van Leeuwen, 2006). Because VRs can enable perception of multiple elements and relations at a glance, they can reduce the need for complex cognitive processing (Hegarty, 2011). The salience of visual information and its ease of understanding may make this information believable (Koerber, Osterhaus, & Sodian, 2017). Finally, evaluation of VRs is also based on knowledge about representation types, conventions, and practices. However, in contrast to knowledge about textual genres and practices, knowledge about visual representation types, conventions, and practices is infrequently taught at school (Eilam, 2012). This could potentially negatively impact learners' capabilities to critically evaluate VRs.

* Corresponding author. Department of Learning, Instruction, and Teacher Education, Faculty of Education, University of Haifa, 199 Abba Khoushy Ave., Mount Carmel, Haifa 3498838, Israel.
E-mail address: sarit.barzilai@edu.haifa.ac.il (S. Barzilai).

https://doi.org/10.1016/j.learninstruc.2018.06.002
Received 11 March 2017; Received in revised form 5 June 2018; Accepted 11 June 2018

Indeed, a recent study indicated that learners can find it quite difficult to critically evaluate online images (McGrew, Breakstone, Ortega, Smith, & Wineburg, 2018).

In light of this background, the objectives of our study were to systematically map learners' epistemic criteria and strategies for evaluating scientific VRs. We also examined if and how learners apply epistemic criteria when evaluating a range of common VR types. To set the stage for our study, we next briefly discuss the nature and functions of epistemic criteria and strategies, the aims and characteristics of scientific VRs, and prior research on how learners evaluate scientific VRs.

1.1. Epistemic criteria and strategies: between knowledge and performance

Epistemic thinking, or epistemic cognition, involves thinking that is related to knowledge and knowing and to the achievement of epistemic aims, such as acquiring true beliefs or understanding (Chinn & Rinehart, 2016; Greene, Sandoval, & Bråten, 2016). According to the AIR model, developed by Chinn and colleagues, epistemic thinking includes three main components: Epistemic Aims and value, epistemic Ideals, and Reliable epistemic processes (Chinn & Rinehart, 2016; Chinn, Rinehart, & Buckland, 2014). *Epistemic aims and value* refer to goals that have a representational nature, such as developing explanations or models, and the importance of these goals. *Epistemic ideals* include criteria or standards that are used to evaluate whether epistemic aims have been achieved and the quality of resulting products. Epistemic ideals can be used to evaluate one's own and others' epistemic products. *Reliable epistemic processes* include strategies or procedures that are likely to result in successful achievement of epistemic aims. Thus, according to the AIR model, epistemic criteria and strategies are valuable because they jointly enable reliable achievement of epistemic aims (Chinn et al., 2014).

Epistemic criteria and strategies have both cognitive and metacognitive aspects (Barzilai & Zohar, 2012, 2014). At the cognitive level, epistemic criteria and strategies are applied to specific information, knowledge claims, or sources (Barzilai & Zohar, 2014; Richter & Schmid, 2010). This can include, for example, judging if a specific visual representation accurately represents a particular phenomenon. The metacognitive level consists of metacognitive knowledge, skills, and experiences related to epistemic criteria and strategies (Barzilai & Chinn, 2018; Barzilai & Zohar, 2014). Specifically, epistemic metacognitive knowledge about epistemic criteria and strategies involves knowledge about what these are, why they are important, when they are used, how to apply them, and conditions on their application (Barzilai & Chinn, 2018). This can include, for example, knowledge about what are important criteria for evaluating visual representations, why these criteria are important, and how one goes about evaluating representations.

Significant relations have been documented between learners' metacognitive knowledge about epistemic criteria and strategies and their abilities to apply these criteria and strategies (Barzilai & Ka'adan, 2017; Barzilai & Zohar, 2012; Weinstock, Neuman, & Tabak, 2004). Furthermore, explicit instruction of evaluation criteria and strategies has been found to enhance evaluation performance (Braasch, Bråten, Strømsø, Anmarkrud, & Ferguson, 2013; Mason, Junyent, & Tornatora, 2014). This suggests that learners' metacognitive knowledge about epistemic criteria and strategies informs their capabilities to employ these criteria and strategies.

Nonetheless, because of their applied nature, the cognitive aspects of epistemic thinking are highly sensitive to context (Barzilai & Zohar, 2014). Indeed, studies that have examined learners' evaluation performance *in situ* have identified differences in the epistemic criteria learners apply under different prompting conditions (Danish & Saleh, 2015; Gerjets, Kammerer, & Werner, 2011) and in different task types (Barzilai & Zohar, 2012). Additionally, discrepancies have been found between learners' stated knowledge of epistemic criteria and standards and their use of these in practice (Iordanou, 2016; Walraven, Brand-Gruwel, & Boshuizen, 2009). This suggests that learners may employ epistemic criteria adaptively, in response to situational cues and demands. Hence, to understand how learners evaluate scientific VRs, it is important to consider both their metacognitive knowledge about relevant epistemic criteria and strategies, and how they apply these in context.

1.2. Scientific VRs and their evaluation criteria

The language of science is multi-semiotic and multi-modal, involving varied representation types (Gilbert & Justi, 2016). According to Kress, Jewitt, Ogborn, and Tsatsarelis (2001), VRs are comprised of signs that their creators determine to be the most suitable for representing the specific meaning they wish to represent about the relevant referents and for conveying this meaning to a particular audience or to oneself. Thus, signs are motivated by the interests of their makers and constitute what their makers believe to be the best form under the circumstances for expressing the meanings they wish to convey.

Scientific VRs are "used for analyzing and understanding many scientific phenomena and are central to the rhetoric of scientific communication" (Roth, 2003, p. 2). VRs have many advantages for promoting understanding and enabling communication. For example, VRs can concretize and represent abstract or implicit relations, causes, or processes; they can afford a holistic rather than linear view of the referent; they may display multiple perspectives on the referent; they can also make comparisons easier; and enable predictions of trends (e.g., Eilam, 2012; Kosslyn, 2006; Mayer, 2014; Taber, 2013).

Various VR evaluation criteria have evolved over time, following the intensive use of representations for conveying information in the sciences and in other disciplines (Hegarty, 2011). Tufte (2001) argued that excellent data graphics should communicate complex ideas with clarity, precision, and efficiency. To do so they should show the data, induce the viewer to think about the represented phenomenon, avoid distorting the data, be concise, and make complex data coherent, among other requirements. Tufte's criteria refer both to the fidelity and quality of the representation of the referent (i.e., *representational criteria*) and to the quality of communication of the information to the viewer (i.e., *communicative criteria*).

Other accounts of VR evaluation criteria have emphasized representational and communicative criteria to varying degrees. diSessa (2002) argued that epistemic fidelity, that is, the accuracy of the representation of the referent, is the fundamental and definitive characteristic of a good scientific representation. Kosslyn (2006) foregrounded communicative qualities and proposed that effective VRs should account for the human cognitive system (e.g., limited capacity of short-term memory) and perceptual processes, focus on the intended audience, contain the right amount of information, and highlight differences among represented entities.

1.3. Prior research on how learners evaluate scientific VRs

Because one of the main goals of science education is to familiarize learners with scientific practices, the acquisition of representational-related competencies (diSessa, 2004; diSessa & Sherin, 2000) has become an important goal of instruction (National Research Council, 2012). Such competencies involve the ability to interpret and critique VRs.

Relatively few prior studies have examined learners' epistemic criteria for evaluating scientific VRs (Azevedo, 2000; Danish & Enyedy, 2007; Danish & Saleh, 2015; diSessa, 2002; diSessa, Hammer, Sherin, & Kolpakowski, 1991). These studies have documented how students critique student-generated representations during or following instructional interventions designed to promote representational competence. The studies revealed that learners, from as early as kindergarten (Danish & Enyedy, 2007), are aware of diverse criteria for evaluating