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Argumentation in GMO infographics and potential enrichment of CLIL science education

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Table of Contents

List of abbreviations

CLIL	Content and language integrated learning
GMO	Genetically modified organisms
SFL	Systemic functional linguistics

List of figures

1. Introduction

Digital environments and global interactions characterize 21st century life. The information age we are in has spurred the need to revise teaching aims (Bernaus et al. 2007: 10; Hilton 2010: 2-3), placing responsibility on educators to foster the development of skills and strategies that students can apply in an ever-dynamic world. Information literacy (e.g. Kohnen & Saul 2018), digital literacy (e.g. Davis & Quinn 2013), visual literacy (e.g. Bucchi & Sarancino 2016; Trumbo 1999), internet literacy (e.g. Harrison 2018), and media literacy (e.g. Andrist et al. 2014) have become common pedagogical research terms, portraying a complex notion of modern education.

Modern education **is** complex. With the seemingly limitless possibilities to obtain, create, and distribute information also comes additional responsibility for using that information (Bucchi 2017: 892). Despite their presumed status as 'digital natives', students need to acquire skills and strategies to deal with the plethora of information online. As Yore, Bisanz and Hand (2003: 711) elaborate,

> "[t]he unique features of the free flow and unedited World Wide Web increase the need for readers with sufficient domain and topic knowledge, metacognitive awareness and executive control of their reading comprehension, and proficiency with the required strategies."

Content and Language Integrated Learning (CLIL), a holistic pedagogic approach conceptualized for European contexts, recognizes and addresses the needed paradigm shift for education in global contexts. Together, the European Centre for Modern Languages (ECML) and CLIL researchers have identified what they call *pluriliteracies* as the core of 21st century learning (Bernaus et al. 2007: 10; Coyle 2015: 94). Pluriliteracy encompasses both plurilingual and pluricultural competency, and refers to "the ability to use languages for the purpose of communication and take part in intercultural interaction, where a person, viewed as a social agent, has proficiency, of varying degrees, in several languages and experience of several cultures" (Council of Europe 2001: 168 in Bernaus et al. 2007: 10). This model emphasizes the development of subject-specific literacies as a means of fostering deep learning (Meyer et al. 2015: 42-43; Meyer, Halbach & Coyle 2015: 2), requiring teachers to see beyond the traditional boundaries of their respective subjects.

Scientific literacy, a broad concept closely associated with "what citizens need in order to participate effectively in society that is highly dependent on science and technology" (Blanco-López et al. 2015: 166), is a multifaceted goal of science education. Despite the fact that this term did not arise out of digital developments and the general lack of consensus regarding what constitutes scientific literacy, the concept has acquired a central position in science education discourse and research (Roberts 2007: 731-735). Quality science education needs to be flexible to adapt to the needs generated by a dynamic society. Since science instruction in school "can help prepare students to engage meaningfully with the real world" (Yore, Bisanz & Hand 2003: 711) and since a significant part of the real world is digital, it is imperative that science education address the Web as source of scientific knowledge and as a place of scientific discourse. It is crucial, therefore, that science teachers, in fulfilling their responsibility of preparing students as competent participants in society, guide them in creating connections between content knowledge and economic, social and political contexts.

The notion of integration is at the heart of this thesis in several ways. It aims to bridge conventional boundaries between science and society, science communication and science education, and content and language within science education. Operating within the context of upper-secondary CLIL science education in Austria, this paper highlights the importance of both social and linguistic perspectives in the attainment of scientific literacy. Specifically, this thesis will present an investigation of both linguistic and visual resources used to construct arguments about genetically modified organisms (GMOs) in static infographics, a popular online text type. Awareness of what is being argued as well as the opinions and attitudes transmitted in these arguments is necessary for both science communication and science education goals. This is especially relevant when reading science texts that present aspects of research that are less well-established or are a point of controversy, such as GMOs.

The first part of this paper lays out the contextual dimensions of the research. Chapter two provides an overview of CLIL; its origins, its intentions, and its perspective on learning. Following this, the popular but vague concept of scientific literacy is explored, beginning with the origins and interpretations of scientific literacy, how the concept has evolved with technological advancements, and then the various ways in which science education and science communication relate both to each other and to scientific literacy. Then, two core approaches to scientific literacy are described. In chapter four, infographics are defined, followed by a discussion of their potential use in educational settings. Chapter five briefly introduces what genetically modified organisms are. Finally, there is an introduction to argumentation; what it means for the practice of science, science education, and how it can be examined.

The remaining part of this thesis presents the conceptual and practical aspects of the research itself. After introducing the research questions, the conceptual framework and tools used in the analysis are described. This is followed by the analysis and discussion of the results, which are ultimately connected back to CLIL teaching aims.

2. CLIL

Given the emphasis on global perspectives in today's society, Europe's diversity in language and culture, and the expectation that secondary school graduates be proficient in at least English, it is unsurprising that Content and Language Integrated Learning (CLIL) has received considerable attention throughout Europe since its inception in the 1990s (Coyle 2007: 543-545). CLIL has been proclaimed "a tremendous success story" (Meyer 2010: 12) and "a language teaching approach [one] simply can't afford to ignore" (Bowler 2007: 2). Although CLIL does have its critics, it nevertheless offers adaptable tools for providing well-rounded education.

2.1. Defining CLIL

CLIL is defined as “a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language” (Coyle, Hood & Marsh 2010: 1). In giving explicit attention to both content and language, “CLIL seeks to connect learners to the realities of using different languages at different times for different purposes” (Coyle 2015: 86). The contextualization of language learning through thematic units is typical of foreign language teaching today, but CLIL goes beyond this type of content-based teaching. CLIL lessons take place in content classes, in which the subject’s curriculum provides the content for language learning. These content courses are not simply taught in a foreign language but are based rather in the reconceptualization of the role of language (Coyle 2007: 552), addressed in more detail below. Consequently, CLIL is considered by some to be “an ideal site for fomenting awareness of the role of literacy across the curriculum” (Whittaker & Acevedo 2016: 38).

As a so-called umbrella concept that incorporates several methodologies (Coyle 2015: 88; Coyle, Hood & Marsh 2010: 3; Hüttner & Smit 2014: 163), CLIL is an admittedly broad approach, but also fundamentally flexible. This flexibility is considered an intrinsic characteristic that allows adaptation to specific teaching and learning situations (Coyle 2015: 86). As Ioannou-Georgiou (2012: 495) describes it, CLIL is a “puzzle” that requires deliberate piecing together in order to make sense and be effective. Local language and educational contexts are important variables in this puzzle (Hüttner & Smit 2014: 163-165), not to mention the heterogeneity of learners that characterizes most educational contexts.

CLIL’s breadth and flexibility make way for varying interpretations and even misunderstanding. Criticism concerning the inclusivity of CLIL and its distinction from other foreign language teaching approaches (cf. Bruton 2013: 580-590; Cenoz, Genesee & Gorter 2014: 244) usually convey a desire for strong boundaries, which defy the essence of CLIL. From the beginning, CLIL has been purported to be a blend of other approaches and methods (Pérez Cañado 2017: 81-82), as the adoption of a strict categorical view could discourage communication and cooperation between educators and researchers (Cenoz, Genesee & Gorter 2014: 258). A detailed discussion regarding these matters goes beyond the scope of this thesis; however, it is important to acknowledge that open-minded discussion of these issues, critical reflection and rigorous research are needed to strengthen the application of CLIL, as with any pedagogical approach. As Meyer (2010: 13) stresses, "embracing the CLIL approach does not automatically lead to successful teaching and learning".

2.2. The 4Cs: some pieces of the puzzle

As signified by the acronym itself, CLIL education is rooted within the notion of integration. Integration requires a "deeper and complex conceptualization of learning" (Coyle 2015: 89) that challenges a conventional separation of language and content. However, the level of integration involved in planning a CLIL lesson, from local parameters to subject matter, language, and competences, requires an adaptable framework. The 4Cs conceptual framework, shown below in Figure 1, provides this flexibility and can be applied to any subject matter.

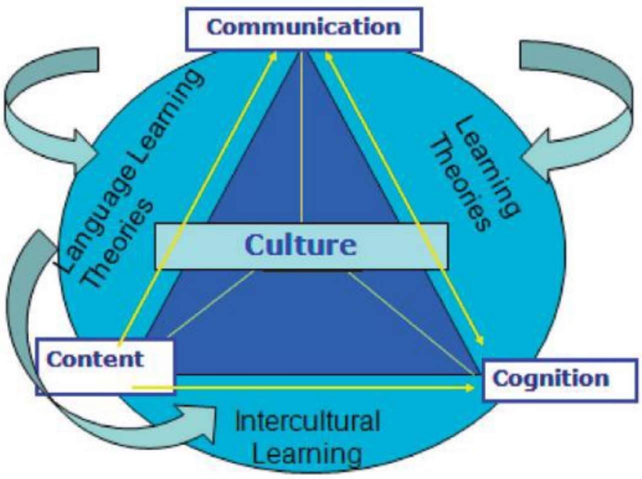

Figure 1. The 4Cs conceptual framework (Coyle 2015: 89).

Content, cognition, communication and culture are the core components that comprise the 4Cs, which are primarily embedded in a philosophical approach to education in general (Coyle 2007: 551). In other words, comprehensive learning theories and those specific to language learning, as well as notions of intercultural learning, serve as the bedrock upon which subject matter, thinking processes, language in its various forms, and social awareness interact with each other. Specifically, constructivism, cognitive theory and functional views of language drive these components and the methodologies applied to implement them (Pérez Cañado 2017: 83-85). The purpose of the 4Cs framework is to illustrate the elements that should be included in CLIL learning to ensure a "quality learning experience" (Ioannou-Georgiou 2012: 499).

Content as subject matter may seem straightforward; just look at the curriculum to gain an idea of knowledge and skills to be acquired. However, it is important to keep in mind that content is intrinsically "meaningless unless it is conceptualized" (Meyer et al. 2015: 52). This requires active learning on the part of the learner, involving a combination of general and subject-specific strategies and skills (Meyer et al. 2015: 51), to go beyond simple knowledge acquisition to knowledge construction (Coyle 2007: 550). In other words, learning needs to be personal (Meyer 2010: 12). Accordingly, the learning of content becomes necessarily intertwined with communication, cognition, and culture.

Cognition plays an indispensable role in learning. Without it, acquisition of content knowledge and skills would be impossible. In CLIL, emphasis is placed on challenging learners to construct their own understanding (Coyle, Hood & Marsh 2010: 54). This involves age- and level-appropriate engagement in both lower-order (e.g. remembering, understanding, applying) and higher-order thinking (e.g. analyzing, evaluating, creating) with the goal of developing proficiency in higher-order thinking that can be applied for further learning. The development of higher-order thinking skills (HOTS) as an educational objective is nothing new; Bloom's (1956) *Taxonomy of Educational Objectives* has proven to be an influential publication in education (Dalton-Puffer 2013: 221). HOTS remain as relevant as ever in today's information-saturated media landscape (Meyer 2010: 21). However, while content subject teachers already plan for the development of HOTS, they are less accustomed to planning for and incorporating the crucial links between HOTS and language (Coyle 2015: 90). This can present a challenge for both CLIL teachers and students, as students' level in the target language is presumably lower than their cognitive learning level (Coyle 2015: 90). In considering this component, it is crucial that teachers examine the linguistic demands required to exercise these cognitive processes (Coyle 2007: 551; Meyer 2010: 12).

Communication is the language aspect of CLIL. It is through this multifaceted concept that the underlying functional linguistic perspective is evident. CLIL is based on the principle that language "cements meaning-making and understanding (cognition) of the subject matter (content understanding) with the language used to learn, communicate and to externalize and internalize understanding" (Coyle 2015: 90). Subsequently, a broader understanding of the role of language for learning is required (Coyle, Hood & Marsh 2010: 36-38), illustrated by the Language Triptych in Figure 2. Here the target language is approached from three angles: language of learning, which generally involves content-specific terminology, grammatical structures and other features that enable students to acquire relevant concepts and skills; language for learning, the language learners need to process their understanding and participate in classroom activities in the target language; and language through learning, which encompasses the new language and new meanings acquired through engagement with the content. Grammatical structures and other formal aspects of language are naturally still considered, but alone are insufficient in supporting the metacognitive and communicative functions needed to develop academic literacies (Coyle 2015: 91).

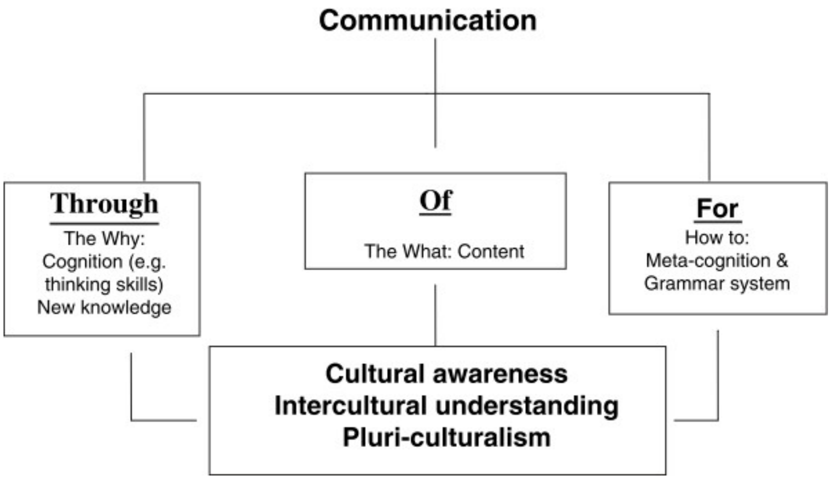

Figure 2. The language triptych (Coyle 2007: 552)

The last though certainly not least important of the 4Cs is culture. The term *culture* itself is admittedly broad and open to interpretation, yet fundamental to 21st century learning (Coyle 2015: 92), and thus to CLIL (Coyle, Hood & Marsh 2010: 39; Meyer 2010: 12; Meyer et al. 2015: 52). Cultural elements permeate education, whether at the institutional or classroom level (see Deng 2011: 46), and in CLIL this relationship is more candid. Culture's central placement within CLIL reinforces its influence on the other Cs. Quality CLIL education not only explicitly identifies cultural objectives and seeks out connections with target language communities but creates opportunities for intercultural learning within the subject culture (ECML 2007). This may seem less straightforward in math or science-based subjects than in history, for example, where human society takes center stage; however, culture is not any less relevant. After all, "it is the subject *C-Culture* that determines how the *C-Cognition* is put to use in the way that *C- Content* will be *conceptualised* and how *C-communication* is *used* to (co-)construct knowledge" (Meyer et al. 2015: 51). Science can be characterized by its inquisitive, tentative and explanatory nature. A unit on biotechnology such as genetic engineering (e.g. BMBWF 2018) may incorporate recalling basics of genetics and describing the process, as well as predicting, analyzing and reflecting on possible effects of such a procedure, both immediate (e.g. short-term, to the manipulated organism) and more remote (e.g. long-term, to an ecosystem or community). This involves reviewing terminology related to genetics and describing cause and effect, as well as reading comprehension and discussion strategies. The combination of different cognitive processes enables a holistic conceptualization of the topic, from the way science works within the scientific community to the way science affects community.

Each component of the 4Cs influences and is influenced by the others, making it difficult to consider them in isolation. Indeed, it is the integration of these elements that lies at the heart of CLIL, and this thesis. Neither purely content-oriented nor purely communicative approaches can be successful in promoting deep learning (Meyer, Halbach & Coyle 2015: 7), nor is it sufficient to merely link content and language learning (Meyer et al. 2015: 53). The interdependence of content, cognition, communication and culture promotes innovative thinking that defy conventional categorical boundaries.

2.3. Pluriliteracies model

Although the 4Cs framework guides teachers regarding the main elements of quality CLIL, this framework alone does not address how these components should be integrated to best support learning. In response to uncertainty surrounding integration, CLIL researchers working under the name The Graz Group developed a pluriliteracies approach (Coyle 2015: 93-94) with the purpose of enabling teachers to recognize the value of pluriliteracy and supporting their incorporation of suitable practices (Meyer et al. 2015: 48-49).

The prefix *pluri-* is significant here. The term *pluriliteracies* encompasses the development of subject literacies, recognizing not only that CLIL learners develop these in and through an additional language, but also “the need for education to consider plurimodal semiotics” (Meyer et al. 2015: 49). The dynamic nature of 21^{st} century learning, with its technological, global, and multi-semiotic elements, requires a view of literacy that is equally dynamic and multifaceted (Unsworth 2001: 8). Working off a definition of literacy focused on recognizing, analyzing, and creating meanings in a range of contexts (Crane 2002: 67 in Coyle 2015: 96), this approach emphasizes the role language and other meaning-making resources have in learning.

Subject literacies are considered to be essential to deep learning and language is critical to their development (Meyer, Halbach & Coyle 2015: 2). Knowledge of subject-specific facts, concepts and procedures are an unquestionably crucial aspect of subject literacies (ibid.; see also Roberts 2007: 735), but they alone are insufficient. A learner needs to develop strategies to navigate new situations and acquire new knowledge and skills; these are a result of deepening and intensifying the learner's conceptual understanding, the key to which is language (Meyer, Halbach & Coyle 2015: 2). In other words, "[e]ducation cannot be separated from language, for education comes about through language" (McCabe & Whittaker 2006: 4). It is through this concentration on the development of subject literacies through language that CLIL's pluriliteracies approach endeavors to operationalize the integration of content and language.

3. Scientific literacy

Scientific literacy is a big buzzword but, like many notions of academic literacy, it is also an ambiguous concept. It is touted as a goal of many science education programs around the world, and Austria is no exception (BMBWF 2018). What follows is a review of scientific literacy from a few varying key perspectives. First, the origin of the term itself and subsequent endeavors to define it are explained. The significance of modern technology, especially communication technology, in the conceptualization of scientific literacy in science education is then examined. This leads to a discussion of why considerations from science communication, a field traditionally separate from science education, are relevant for modern science education. Finally, two seemingly conflicting perspectives on scientific literacy, both pertinent to this investigation, are introduced and dissected, demonstrating that they are not incompatible.

3.1. Origins and interpretations of scientific literacy

Science education has been long regarded as beneficial to students' educational development, regardless of their intent to pursue science later in life (Feinstein 2011: 168). Indeed, science education has been an integral part of general education in both Europe and the USA for almost two centuries (DeBoer 2000: 583). The focus and aims of science education have shifted, however, as a result of the dynamic relationship between science and society. Curriculum development was once driven by goals concerning the understanding of the natural world, creating future scientists, and providing future generations with sufficient knowledge to be receptive to scientific developments. But mounting recognition of the potentially destructive nature of certain advancements in science and technology awakened calls for new approaches to science education (DeBoer 2000: 584-585).

Scientific literacy began as a slogan rather than a specific educational goal. Hurd (1958) and McCurdy (1958) are credited with being among the first to address the concept of scientific literacy (Barsam-Tsabari & Osborne 2015: 136; DeBoer 2000: 582). They emphasized the need for a dynamic approach to education (Hurd 1958: 14), the value of integrating science and society through the reflection of social problems using scientific knowledge (Hurd 1958: 16), the importance of understanding the public (McCurdy 1958: 367), and the obligation to educate students in such a way that they can "sift fact from fancy" (McCurdy 1958: 367). While Hurd and McCurdy both made convincing appeals for a renewed focus in science education, neither provided a clear definition. *Scientific literacy* has thus primarily operated as a "rallying cry" (Pearson, Moje & Greenleaf 2010: 459) for curriculum reform, and largely remains a vague concept.

Despite subsequent efforts to define scientific literacy, there has been no success in formulating a universal definition (DeBoer 2000: 582; Feinstein 2011: 13). Differing interpretations of the slogan have resulted in different approaches, contributing toward a plethora of definitions (Roberts 2007: 736-737), a phenomenon common to subject-specific literacies due to the "'socially contested' nature of literacies" (Gee 1996: 22 in Meyer et al. 2015: 42). Even the term itself for science-specific literacy is not completely clear. Some authors refer to *scientific literacy* (e.g. Cavagnetto 2010; Fang 2004), while others use the term *science literacy* (e.g. Feinstein 2011; Hand et al. 2003); some consider the terms distinct from each other, while others find the difference inconsequential (Roberts 2007: 730-731). To add to the confusion, *scientific/science literacy* is just one of several concepts widely used to describe science education goals related to "what citizens need in order to participate effectively in society that is highly dependent on science and technology" (Blanco-López et al. 2015: 166), making the term virtually impossible to ignore. For the purposes of this paper, the difference between the two terms is insignificant, but I will refer to *scientific literacy* for consistency, because of the term's international reach (Roberts 2007: 730), and its presence in Austrian curriculum documents (BMBWF 2018).

Working without a clear definition is difficult. This sort of ambiguity can have adverse consequences for the comparability of research and can be frustrating for anyone looking for consistent and concrete answers (Roberts 2007: 735). Still, not everyone agrees that a universal definition is essential. DeBoer (2000: 582) considers the term's breadth intrinsic and necessary, as it incorporates important historical context, reflecting how science education has shifted over time. Context is equally fundamental for Roberts (2007: 735-736), who ponders whether scientific literacy is a worthy goal to strive for anyway. He claims that such an ideal is impractical in policy formation, since the value of particular types of knowledge and skills will differ based on the local context. This context, in turn, influences the development of educational programs, which may challenge any idealized definition of scientific literacy. Nevertheless, new technological advancements have once again triggered the need to reconceptualize the role of science literacy in school science education, this time on a global scale (Linder et al. 2011: 1).

3.2. Modern developments and their implications for scientific literacy

The implications of our digital, globalized world for science education are unmistakable. On the one hand, there is excitement about the opportunities the digital landscape presents. It offers both exposure to a wide array of different types of scientific writing and may encourage insightful questions regarding science-related decisions (Yore, Bisanz & Hand 2003: 708-709). Additionally, the fundamentally multimodal nature of science (Lemke 1998: 87) is significantly enhanced in the digital landscape (Bucchi & Sarancino 2016: 813). Multimodal resources are widely considered to be beneficial in science education and science communication, as they help to increase engagement with science content (Polman & Gebre 2015: 769, 781). Science educators have a vast library of multimodal resources at their disposal, which not only provide access to lesson materials, but also opportunities to examine scientific processes and products from various perspectives.

On the other hand, there is uncertainty about knowledge transfer via the internet. Expert and popular domains are no longer distinct (Bucchi 2017: 891), as both scientists and non-experts use the affordances of the internet to communicate, discuss, and produce science-related content (Brossard 2013: 14096). Consequently, there are concerns about the accuracy and trustworthiness of information online, not only relating to authorship and quality, but to the effect the complex online environment (e.g. algorithms, comment sections) may have on this information and thus knowledge and attitudes about science (Brossard 2013: 14096-14100; Bucchi 2017: 890-892). The diminished role of traditional gatekeepers like science journalists places the burden of information credibility elsewhere (Lim, Nekmat & Nahar 2011: 179), in many cases on consumers themselves (Bucchi 2017: 892). The challenges of consuming science information in digital environments are manifold (Lim, Nakmat & Nahar 2011: 170-174); there is a dominance of multimodal presentations in various constellations, content can be manipulated and generated by almost anyone, and traditional content classifications are constantly reconstructed.

However, digital landscapes have undoubtedly brought science and society closer together. Conventional and misleading characterizations of science as detached from society have long propagated what Lemke calls the “mystique of science” (Lemke 1990: xi, 134), a harmful notion of science as impersonal, objective, and elitist (Lemke 1990: xi, 129). The affordances of the internet have pulled science into the public sphere, revitalizing the classic debate about the importance of science knowledge for participation in society (Feinstein 2015: 145-146).[1] Contemplating the role of scientific knowledge for the average citizen in the internet age, Feinstein (2015: 157) identifies three challenges for science education:

> First, […] science education research, as a field, should balance its attention to prior knowledge with a similar attention to the non- scientific frames and narratives that people use to interpret news about science. […] Second, […] students need to learn more about […] the second shaping of scientific facts—how they are packaged into stories by the formal news media as well as other, less institutional sources. […] Third and finally, [there needs to be] more attention to the new and creative platforms for public engagement that science communication researchers have started to explore.

The following investigation into positions on GMOs in infographics can be considered an attempt to rise to these challenges. Science-related infographics often include political, economic and ethical perspectives; they require active choices on the part of the text’s creator regarding what to include and omit; and have become one of several creative ways to communicate information online.

Modern tools, new texts types and the ability to easily interact with science content online all demonstrate the central role of communication in science as

[1] In the United States in the 1920s, there was a philosophical discussion between Walter Lippmann, journalist and social commentator, and John Dewey, philosopher and educational reformer, about the capability of citizens to participate in civil debates that require specialized knowledge (Feinstein 2011: 145). Although they shared similar concerns, they took different stances on whether expert collaboration with the public could help the average citizens to educate themselves (Crick 2009: 482-483; Feinstein 2011: 156, 157-158). Crick (2009) and Feinstein (2011) recap the focal points of the debate and discuss their relevance to the internet age and scientific literacy, respectively.

well as highlight the increasingly intertwined worlds of experts and non-experts, science communication and science education.

3.3. Science education and science communication

The multifaceted and ubiquitous role the internet has in today's society blurs many traditional barriers. Because the internet is used by nearly everyone to access information and communicate, school-aged children included, educators not only have an obligation to address what and how information is broadcast online but to equip students with the appropriate tools to navigate this environment independently. Though science education and science communication have traditionally been thought of as distinct fields (Barsam- Tsabari & Osborne 2015: 135), the pervasiveness of internet technology only serves to strengthen arguments for interaction and cooperation between the fields.

Science communication is a relatively young and still developing research area (Bucchi & Trench 2016: 151-152) with a general focus on using the media to encourage interaction between the general public and science (Davis & Russ 2015: 222). Critical stances are not uncommon in science communication, where there is emphasis on the contingent nature of scientific knowledge (Barsam-Tsabari & Osborne 2015: 135-136). Conversely, science education tends to have a younger audience, and emphasizes the teaching and learning of science (Davis & Russ 2015: 222). In these contexts, more significance is placed on knowledge of scientific concepts and practices, rendering them neutral and objective (Barsam-Tsabari & Osborne 2015: 135-136).

These two broad disciplines leave much room for overlap, however. The overarching aims are similar: to help "non-experts and non-members of the professional science community develop knowledge of the content and processes of scientific research" (Davis & Russ 2015: 222) through education, entertainment and engagement (Barsam-Tsabari & Osborne 2015: 135). Indeed, science education can be considered to be the oldest form of science communication (Russell 2010: 118). Progressively, there have been appeals to recognize and utilize the overlap between these two fields. Davis & Russ (2015: 222) call the dichotomy between science education and science communication "unproductive", arguing that "[p]lacing […] phenomena in only one category runs the risk of producing research that neglects some aspects of the situation while over emphasizing [sic] others, thus providing only a partial picture of the phenomenon" (ibid.). Similar sentiments emphasize a need for science education to use insights from science communication to more adequately acknowledge and address the connections between science and society (e.g. Barsam-Tsabari & Osborne 2015: 135-139; Feinstein 2015: 151-155).

Support for a participatory-constructivist model of learning has been around in science education longer than in science communication (Barsam-Tsabari & Osborne 2015: 139), yet science education is still often associated with the "purist tendency" (Russell 2010: 117) of reinforcing the prestige of content knowledge (see also 3.4.). Over-emphasis of content knowledge is deemed limiting to effective science education (Barsam-Tsabari & Osborne 2015: 137; Feinstein 2015: 151; Linder et al. 2011: 3). While most science teachers might hope to inspire their students to pursue science-related careers, the majority of students will not; in fact, they may not even enjoy science. Conversely, science communicators and science communication researchers engage with perspectives of those outside the scientific sphere, dealing with topics that are of particular interest or are relevant to public concern (Feinstein 2015: 151-152). They are more likely to address the various influences on how science and its impact on society are interpreted, whether that be social identity, community values or personal emotions (Barsam-Tsabari & Osborne 2015: 137).

It is precisely because of this different perspective, as opposed to a strict disciplinary focus, that science communication can benefit science education. Science communication's focus on socio-scientific issues is especially relevant to science education (Barsam-Tsabari & Osborne 2015: 137-138; Feinstein 2015: 151-152). Socio-scientific issues comprise a wide range of problems, questions and dilemmas, whether personal or societal, broad or specific (Lenz & Willcox 2012:

553-554). They are conceptually founded in science, but also emerge in society as ethical, political and economic concerns (Tidemand & Nielsen 2017: 45). Incorporating such issues and varying perspectives not only provides a context for scientific concepts but can increase student motivation and engagement (Lenz & Willcox 2012: 553; Tideman & Nielsen 2017: 44). Furthermore, engagement with the various media that convey information about science and science-related issues is critical for developing scientific literacy.

Whether or not students pursue scientific interests, science will continue to play an important role in making informed decisions. These may concern private matters such as diet and lifestyle or public issues like support for legislation. As Fischhoff (2013: 14033) remarks, "[a]though people can choose not to do science, they cannot choose to ignore it". Comprehending, evaluating and applying science-related information is part of the role of a competent citizen (Davis & Russ 2015: 221), and teachers need to prepare students for that role. The media will become students' main source of information about science and science-related issues after they graduate (Jarman & McClune 2009: 309). Therefore, not only is knowledge of science content and the nature of science necessary to engage critically with media portrayals of science-related topics, but so is knowledge of the nature of media itself (Jarman & McClune 2009: 323). Focusing solely on traditionally scientific perspectives in science teaching is to do our students a disservice. Instead of producing what Feinstein (2011: 180-181) calls "competent outsiders", individuals who recognize when science is relevant to their lives and can interact meaningfully with and apply relevant information, we produce "marginal insiders", individuals who have a rudimentary understanding of scientific concepts without a real understanding of the complex and less straightforward interactions involved in doing science, which does not translate into everyday competence. Engaging explicitly with socio-scientific issues in the classroom is one step towards giving students the knowledge and skills they need to become competent outsiders.

3.4. Bridging science and society: Roberts' visions on scientific literacy

Specialist knowledge is certainly important in developing scientific literacy, but the interactions between science and society are just as important if we want to promote students' full and responsible participation in society. While there is a large variety of context-specific conceptualizations of scientific literacy, there is substantial support for approaches that include an emphasis on socio-scientific contexts.

An influential perspective on the inclusion of socio-scientific issues and non-scientific considerations in scientific literacy comes from Roberts (2007; 2011), who has comprehensively surveyed the varied orientations to scientific literacy. Roberts avoids the problematic field of definitions by characterizing the main approaches into what he calls "visions" (Roberts 2007: 730; Roberts 2011: 11-14). Vision I and Vision II of scientific literacy represent two ends of a spectrum that act as conflicting influences on the science curriculum (Roberts 2007: 730; Roberts 2011: 11-12). These broad visions encompass a wide range of scientific literacy definitions and are distinguished from each other through their "over-arching purpose for which a student is to learn scientific meaning" (Roberts 2011: 14).

Vision I of scientific literacy is said to "look inward" (Roberts 2007: 730; Roberts 2011: 14). Scientific literacy definitions that lean more towards Vision I place significance on the acquisition of increasingly complex scientific knowledge (Roberts 2011: 14), privileging the "canon of orthodox natural science" (Roberts 2007: 730), meaning the "products and processes of science itself" (ibid.) The primary rationale behind this vision is to cultivate future scientists (Roberts 2011: 13). Because Vision I definitions of scientific literacy have traditionally informed curricular development (Roberts 2007: 730; Roberts 2011: 24), it generally enjoys higher status, making it challenging to implement other perspectives (Roberts 2011: 12, 24).

At the other end of the spectrum, Vision II assumes an outwardly oriented position. Key to this orientation are non-scientific ideas and concerns. Socio- scientific issues serve as the basis for Vision II definitions of scientific literacy (Deng 2011: 45; Roberts 2007: 753; Roberts 2011: 23; Zeidler & Sadler 2011: 176). These may include, but are by no means limited to, understanding aspects of daily life through scientific explanations, learning how cultural contexts influence explanations of phenomena, or recognizing the effect personal values and attitudes have on scientific research and the application thereof (Roberts 2011: 14). According to Roberts (2011: 24) and others who have explicitly adopted Vision II as the launching point for their work (e.g. Aikenhead, Orpwood & Fensham 2011: 30-32; Deng 2011: 45; Polman et al. 2014: 770; Zeidler & Sadler 2011: 176), this lens offers opportunities for achieving 21st century scientific literacy goals.

Although the emphasis on socio-scientific issues has found plenty of support, it is important to remember that Vision I and Vision II are polarized ends of a continuum. Roberts himself (2011: 16) emphasizes the danger of extreme interpretations of these visions. Despite the widespread recognition that science is influenced by cultural norms, and is hence subjective (Cavagnetto 2010: 339), this does not suggest that a strictly Vision II approach to scientific literacy is appropriate. Such a radical approach would ignore the role of science itself and the responsibility of those, including students, with relevant scientific knowledge (Roberts 2011: 16). Regardless of the diverging opinions concerning what should constitute the core of scientific literacy, there seems to be one point of consensus, namely that it is impossible to be scientifically literate without knowledge of science subject matter (Roberts 2007: 735). As any specific view of scientific literacy will be context-dependent (Roberts 2011: 13; see section 3.1.), any quality science curriculum will incorporate aspects of both visions, perhaps to differing degrees.

However, because Vision I has had a dominant influence on science education for decades, advocates of more inclusive science teaching are appealing to educators to recognize the competing influence of these two ideas of scientific literacy and offset the deep-rooted advantage of Vision I (Roberts 2011: 24). Yet research has shown that the effective implementation of socio-scientific issues in science teaching faces a range of obstacles, ranging from perceived time and curriculum constraints to assessment concerns to teachers' lack of confidence (Tidemand & Nielsen 2017: 45-46). In their own survey of Danish biology teachers, Tidemand and Nielsen (2017: 46-58) found that, despite the established incorporation of socio-scientific issues in the curriculum and teachers' general positivity towards this approach, teachers' interpretations of socio-scientific issues were predominantly content-centered. These findings, while not representative, suggest there is still room for discussion on how to address the implementation of socio-scientific issues on all levels – institutional, programmatic, or in the classroom (see Deng 2011: 45-46).

Teachers have a social responsibility to go beyond the facts. Science teachers are not merely teachers of science content but are also helping to prepare students for life beyond school, irrespective of their career goals. Awareness of and engagement with issues that link societal and personal concerns with science activity are widely accepted as part of this preparation. This is reflected in the Austrian upper secondary curricula for biology as well, where learning outcomes include the ability to scrutinize the advantages and risks of new scientific developments and technologies (BMBWF 2015: 8), recognize connections between science and other fields such as math, economics, and social sciences (BMBWF 2019: 5), and participate actively in public discussions (BMBWF 2018). Consideration of socio-scientific issues also fits nicely into the CLIL concept, in which cultural aspects should play a central role. It is still necessary, however, to consider students' non-native speaker status and foster the development of language strategies that help them access cultural meaning.

3.5. Reading as scientific literacy

3.5.1. Back to the roots: a fundamental sense of scientific literacy

Although the comprehension of and ability to apply scientific concepts is at the center of most contemporary interpretations of scientific literacy (Burns, O'Connor & Stocklmayer 2003: 187), literacy in its more basic sense, as the ability to read, comprehend, and produce texts, has been regaining traction in science education (Cavagnetto 2010: 337; Liberg, Geijerstam & Folkeryd 2011: 74; Roberts 2007: 750; Wellington & Osborne 2001: 1; Yore, Bisanz & Hand 2003: 691). In fact, several researchers advocate that science teachers acknowledge themselves as language teachers as well (Fang 2004: 345; Hand et al. 2003: 612-613; Lemke 1990: 172; Norris & Phillips 1994: 964; Wright et al. 2016: 1278). A leading approach to scientific literacy from this perspective comes from Norris and Phillips (2003), who distinguish between two meanings of literacy: the fundamental sense and the derived sense. The fundamental sense of scientific literacy generally deals with reading and writing skills, while the derived sense is about possessing content knowledge and the nature of science (Norris & Phillips 2003: 224). The relationship between these two senses is considered to be "constitutive" (Norris & Phillips 2003: 226); without the fundamental skills of reading and writing, a derived sense would not be possible.

Central to this position is the underlying role language has in science. Without language, scientific knowledge could neither be created nor communicated (Kelly 2011: 61; Savory 1967: 143; Yore, Bisanz & Hand 2003: 691). There are numerous ways to 'do' science through language, from describing and classifying phenomena to reporting findings and formulating theories to asking questions and teaching students (Lemke 1990: ix; Halliday 1998: 185). In perhaps one of the first endeavors to merge scientific and linguistic perspectives, Savory (1967: 18) addressed the question of whether a language of science exists, answering in the affirmative with his lengthy description of the technical nature of the discipline's vocabulary and its informative, non-emotive style (Savory 1967:

72-127). Much work on language and science and scientific literacy has been done from the perspective of systemic functional linguistics (SFL), which views language as a social semiotic (see sections 3.5.2. and 5.2.). Researchers working within this framework consider there to be an intimate link between the evolution of science and the evolution of scientific language (Halliday & Martin 1993a: 12), implying an interdependence between learning the discipline and its language. Instrumental in understanding the abstract nature of scientific language has been Halliday's (e.g. 1993, 2006 [1995]) work on the development and function of grammatical metaphor in English, generally considered to be a source of difficulty for students, regardless of their native or non-native speaker status (Halliday 1993: 68). Using SFL, researchers have analyzed canonical science discourse from both professional (what scientists do) and educational (what students are expected to learn) angles (Martin 1998: 3-4), identifying, describing and categorizing typical functions of science texts (Martin & Rose 2008: 141-179).

Knowing the language of science has long been recognized as fundamental to understanding and participating in science at all levels. Both text consumption and production are important for scientific literacy; the focus here, however, will be on text consumption. Exposure to authentic texts and contexts is considered vital for subject language acquisition, not only in terms of form but of function as well, allowing for notions of communication to be examined (Coyle, Hood & Marsh 2010: 32). However, exposure alone is insufficient for true comprehension (Fang 2006: 516). It is necessary to move beyond the myth that equates reading to decoding text and develop interpretive and analytical means of understanding (Gee 1996: 40-41; Hand et al. 2003: 612; Norris & Phillips 2003: 226). Metalanguage, or language about language, is one essential resource for developing such critical literacy skills (Unsworth 2001: 15). Explicit handling of the role of language in science can positively impact students' language learning in general (Martin 2009: 15-16), and therefore scientific literacy, whether in the form of understanding of scientific concepts, production of texts or attitudes about science (Hand et al. 2003: 609;

Fang 2006: 607; Halliday & Martin 1993b: 24-26; Lemke 1990: 170; Yore, Bisanz & Hand 2003: 691, 699).

3.5.2. Socio-scientific aspects of the fundamental sense

While a grasp of scientific language is undoubtedly a critical part of comprehending scientific concepts and therefore integral to secondary science education, societal and cultural connections may be overlooked. Roberts himself (see section 3.4.) considers this the case with Norris and Phillips' (2003) approach to scientific literacy, citing their work as an example of research aimed at "[o]pening that black box [of the meaning of literacy in the scientific literacy concept] from the point of view of Vision I" (2007: 750). I would argue, however, that these views are not incompatible. The extent to which the relationship between fundamental and derived senses of scientific literacy occupies solely Vision I territory is dependent on several factors, such as one's understanding of what the derived sense of scientific literacy means, the adoption of a social semiotic perspective, and the types of texts examined.

3.5.2.1. A social semiotic perspective

First, a social semiotic perspective can encourage prioritization of socio-scientific issues. Semiotics deals with the various sign systems used to communicate meanings. This is not restricted to language, although language in its written and oral forms have always been a significant mode of expression in scientific discourse (Hand et al. 2003: 608). Social semiotics approaches meaning from a constructivist angle; in other words, utterances, objects, or actions are not assumed to inherently possess meaning, rather meaning is made for these by users (Lemke 1990: 186). The study of language as a social semiotic deals with the interpretation of language in its sociocultural context (Halliday 1978: 2). As a meaning-making resource, language "transforms experience into meaning" (Halliday 2006 [1995]: 11). From this perspective, science texts cannot be considered mere "static entities" (Davis & Russ 2015: 222) that channel information directly to readers; the actions and perspectives of scientists, communicators and the general public shape the what, how and why texts are produced (Davis & Russ 2015: 222). As products of meaningful interactions, they are semiotic texts (Lemke 1990: 195-196) and carry social meaning.

Reading any semiotic text can therefore be understood as an active process in which the reader recreates meaning by combining the information from the text itself with their own knowledge (Bazerman 1985: 3-4; Hand et al. 2003: 612; Norris & Phillips 2003: 228; Yore, Bisanz & Hand 2003: 698, 705). Reading essentially goes beyond the words on a page. It encompasses not only comprehending the text, which involves understanding the content and language resources used (Liberg, Geikerstam & Folkeryd 2011: 79), but interpreting, analyzing and critiquing it, too (Norris & Phillips 2003: 229). These are the same mental processes involved in doing science (Pearson, Moje & Greenleaf 2010: 460; Norris & Phillips 2003: 230). If science teachers, in their role as language teachers, go beyond the instruction of vocabulary and formal grammatical structures, they can "create in students a sensitivity to the complexity and nuance of scientific discourse" (Norris & Phillips 1994: 964). In this way, reading science-related texts can be considered both a form of and tool for scientific inquiry (Pearson, Moje & Greenleaf 2010: 459-460; Rainey et al. 2018: 377). Knowledge of linguistics and systematic reflection of language in use can help identify significant linguistic features and connect them to its impact on a text of reader (Macken-Horarik et al. 2015: 146). Implemented in this manner, an emphasis on the fundamental sense of scientific literacy draws attention to the social factors inherent in using language or other semiotic resources. In other words, analysis of the meaning- making resources used in science texts is simultaneously the engagement with the norms, values, and various interests involved in scientific knowledge, a key component of Roberts' Vision II (Östman & Almqvist 2011: 160-161).

Especially in science, however, it is not just written language that plays a role in communication and understanding. Visual elements have been integral to human communication since its origin (Kress & Leeuwen 2006: 21; Ogborn 2013: 185) and serve as a powerful semiotic resource. Scientific concepts are semiotic hybrids at their core (Lemke 1998: 87). Scientific practices, teaching science, and communicating about science have always been multimodal to some extent, utilizing spoken language, written language, visualizations, objects, and movements through space. Written language in itself is fundamentally visual and thus multimodal with affordances like font, size and layout (Kress & Leeuwen 2006: 17; Lemke 1998: 95; Unsworth 2001: 9). In addition to this, there is a long tradition of including elements such as tables, graphs, diagrams, and figures with captions in science texts, all of which involve both visual and verbal components, bestowing these texts with non-linear qualities (Lemke 1998: 95-96). The visual nature of science textbooks has also gained significant attention with the recognition that images and other graphic elements have a complementary, if not primary, role in communicating meaning (Ogborn 2013: 186; Prior 2013: 523; Veel 1998: 140-148). In their seminal work on visual design, Kress and Leeuwen (2006: 19) maintain that visuals should be treated as separate and full carriers of meaning. Although there is still disagreement regarding the extent to which images enhance textual representations or operate independently (Hansen 2018: 238), the affordances of visual modes can often make images more explicit than writing (Ogborn 2013: 186, 189). According to Martin (2002 in Unsworth 2006: 69), a basic function of images is to facilitate the communication of attitude, a role that is especially significant when it comes to interpretation and evaluation of information that may potentially influence decision-making.

Although science and scientific discourse are fundamentally multimodal in nature, perpetual advancements in science and digital technologies have intensified the need to address multimodal literacy as part of scientific literacy. While there is an important distinction between multimodality and digitality (Prior 2013: 523), the two often occur simultaneously. With the ubiquity of digital media, the importance of unimodal documents has diminished significantly (Lim, Nekmat & Nahar 2011: 169). Congruent with the pluriliteracies approach put forth by CLIL researchers (see section 2.3.), several scholars investigating multimodality argue for the integration of skills for navigating such media. For example, Lim, Nekmat and Nahar (2011: 175) assert that critical text analysis "lies at the intersection of multimodal literacy and media literacy", which in itself involves a range of literacies. Nevertheless, they place great emphasis on the need to accommodate the modern media landscape (ibid.). Hansen (2018: 238) emphasizes the need to examine visual elements not only as they relate to textual content, but to a wider social context, as this can be significant for the meanings communicated. Likewise, Thompson (2008: 144) emphasizes that content literacy fundamentally encompasses other literacies because various modes of meaning making are involved in content learning; consequently, incorporating multimodal texts in class is vital for acquiring a comprehensive perspective of the content (Thompson 2008: 151-152).

Conceptualizations of fundamental literacy are being redefined. It is generally acknowledged that literacy teaching needs to exceed the realm of language (Unsworth 2006: 55). Just as we teach students to read language, we need to teach them to read the images and other visual elements that constitute the majority of contemporary texts (Daly & Unsworth 2011: 61; Lim, Nekmat & Nahar 2011: 178). Comprehending a multimodal text goes beyond recognition of either text or image. While this may seem more intuitive for written language (see above), it is just as valid for visualizations. Contrary to the traditional assumption that good graphics communicate instantly and easily (Daly & Unsworth 2011: 70; Ogborn 2013: 189), true understanding involves work on part of the reader. Likewise, it is a misconception that today's learners as 'digital natives' can effectively or successfully navigate multimodal content without explicit guidance and access to analytical tools (Daly & Unsworth 2011: 71; Lim, Nekmat & Nahar 2011: 180; Macken-Horarik 2004: 6; Ogborn 2013: 189).

It is important to bear in mind that multimodal documents are human artifacts; they are actively designed and constructed. As a result, they are not arbitrary. By examining texts through a social semiotic lens, the intrinsic social qualities of human language can be unveiled. Even canonical texts laden with Vision I values such as research articles are not void of interpersonal qualities (see Hyland 2010: 116; Martin & White 2005: 1). Any expression of opinion or statement about the nature of relationships between participants necessarily involves socio- scientific concerns. The extent to which a fundamental sense of scientific literacy shares common ground with the goals of a Vision II orientation to scientific literacy is dependent on the extent to which one chooses to devote attention to the functions of semiotic resources.

3.5.2.2. A case for popular science

Another way in which a fundamental sense of scientific literacy can occupy space towards the Vision II end of Roberts' continuum is by integrating texts that deal explicitly with socio-scientific issues. Academic science texts like research articles and textbooks may refer to societal concerns for the purposes of contextualization, but they typically prioritize scientific methods and theories (Parkinson & Adendorff 2004: 388). By contrast, non-academic or popular science texts overtly address scientific issues with connections to current or relevant societal concerns, frequently emphasizing non-scientific perspectives. Popular science texts are valuable resources for exploring these perspectives; in particular, explicit attention to semiotic resources can unveil layered agendas.

As described above (section 3.3.), the field of science communication encompasses interaction between several different actors. An important component of science communication is engaging with non-experts in either formal or non-formal situations. Popular science constitutes a considerable portion of science communication. Bucchi and Trench (2016: 153) describe science popularization as "a wide range of practices in making scientific information accessible to general, non-expert audiences". An established practice since the 18th century (ibid.), popular science can target various subsets of the lay population (Hyland 2010: 118). The existing literature on popular science focuses primarily on articles and books intended for lay audiences (e.g. Fuller 1998; Hyland 2010; Meyers 1990; Miller 1998; Parkinson & Adendorff 2004), written either by scientists themselves or journalists. Articles may appear in various general or science-specific publications like newspapers, magazines and blogs. Additional formats of popular science include evening news stories or science programs on television, museum exhibitions, public forums where various issues are explained or discussed, radio broadcasts, podcasts, and, the focus of this project, infographics, described further in chapter 4.

Popular science texts do not enjoy the status academic science texts do, mirroring the status discrepancy between Vision I and Vision II notions of scientific literacy (see section 3.4.). Despite being an important part of scientific discourse in general, popular science discourses are often seen as separate from and less valuable than academic science discourses. As Hilgartner (1990: 519) describes it, the "culturally-dominant view of the popularization of science is rooted in the idealized notion of pure, genuine scientific knowledge against which popularized knowledge is contrasted". By assuming two separate discourses, this notion of popularization places scientists and scientific institutions as the sole authorities on what is genuine science, and the general public as empty, accepting vessels which scientists can fill with knowledge at will (Hilgartner 1990: 519-520; Meyers 2003: 266). Similar to extreme notions of Vision I scientific literacy and deficit models of science communication, simplistic views of popular science reinforce scientism (Roberts 2011: 14, 15, 22), the view that science is the only true source of understanding (Ridder 2014: 23), and the 'mystique' of science (Lemke 1990: xi, 129), implying clear boundaries between academic and popular science where there are none (Hilgartner 1990: 524, 529). As a result, any differences between 'genuine' and popularized science texts are regarded as "'distortion' or 'degradation' of the original truths" (Hilgartner 1990: 519), regardless of whether these differences are necessary and appropriate simplifications by scientists for educational reasons or arise through misunderstanding and misrepresentations by outsiders (ibid.). These attitudes allow popularizations to be dismissed more easily.

The inferior status attached to science popularization texts is undeserved. Popular science texts are just one of many types of texts and practices involved in scientific discourse (see Norris & Phillips 1994: 951), and popularizations themselves span a continuum of situations and forms (Hilgartner 1990: 528; Meyers 2003: 270). Simplification is not equivalent to degradation, as it is itself directly valuable in scientists' work, whether in the lab or in interactions with various parties (Hilgartner 1990: 522). Hilgartner is not alone in claiming that dominant portrayals of popular science are conceptually flawed. Myers (1990: 143-144), in his discussion of the social construction of popular science, likewise rejects these dominant assumptions of popularization, placing emphasis on the constitutive role language has in science (see 3.5.1.). Changes in language result in changes in meaning. Therefore, popular science texts, like any other scientific text, can serve multiple functions depending on the constellation of semiotic resources. Criticism of popular science as "merely infotainment" (Hyland 2010: 118) or "journalistic dumbing down of science" (Hyland 2010: 119) is oversimplified and fails to recognize the potential functional variety of popularizations (Hyland 2010: 119). If language gives concrete form to science (Meyers 1990: 143), and science knowledge is constructed through the collective transformation of statements (Hilgartner 1990: 524), then the transformative process of populari-zation can be understood as an extension of that knowledge construction pro-cess (ibid.). Accordingly, popular science performs an important public service.

Popularizations are an integral and significant component of scientific dis-course (Meyers 2003: 270), despite a pervasive belief to the contrary. Indeed, as Hyland (2010: 118) indicates, the mere existence of popular science discourses "underlines that 'science' is not a monolithic entity always understood in the same way, but a social construct created by different groups with different interests". Accordingly, scientific discourses cannot be dissociated from other discourses (Meyers 2003: 271), whether political, economic, social or ethical. As a practice of science communication, science popularization is not just a product, but a pro-cess. Popular science can be considered to be a type of translation (Fuller 1998: 35), in which the "forbidding rhetorical features" (Hyland 2010: 118) of academic scientific discourse are removed. Yet beyond that, science popularization is a process that raises questions (Meyers 2003: 267), whether political, economic, or ethical, accentuating the connections between science and society.

Both process and product, science popularization is not only concerned with information but with interaction as well (Meyers 2003: 273). The target audience of popular science texts does not usually consist of scientific experts, at least not in the field of concern. The scientific processes that are emphasized in formal academic texts are not as relevant to a general public audience as to fellow or aspiring scientists. Scientific phenomena are therefore represented differently in popularizations due to the nature of the writer-reader relationship. If the authentic experiences, expertise, and concerns of nonprofessionals are not acknowledged, any tension between science and the rest of society cannot be understood (Meyers 2003: 274).

Consequently, it is important that students are exposed to and understand popular science texts. Searching, selecting, and interpreting scientific information from various popular sources is essential to scientific literacy. If students are to effectively engage with science in everyday contexts beyond their high school education, they must be able to construct meaning from these texts (Norris & Phillips 2003: 236). Engagement with these texts in science teaching puts social concerns in the foreground (Parkinson & Adendorff 2004: 392). For example, the popularizations may serve as an overt response to phenomena within a certain social or political context; examining the language use can help discern if certain values are emphasized over others.

3.6. Argument and argumentation

Characterizations of argumentation vary according to the standards, beliefs and values of the community in question. Legal argumentation will proceed differently from scientific argumentation, for example, and both of those will differ from argumentation that occurs between friends. Yet, a point of similarity between contexts is that purpose or function is central to defining argumentation (Coffin 2004: 230; see also section 5.2.4.). In a very general sense,

> "[a]rgumentation is a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader, by putting forward a constellation of propositions intended to justify (or refute) the standpoint […]" (Eemeren et al. 1996: 5).

The following sections take a closer look at argumentation in science and present the reasons for examining argumentation texts in science teaching.

Argumentation in science is regarded as unique by virtue of its importance to the nature of science. The constitutive role language plays in science has already been established (see section 3.5.). Argumentation is a fundamental element of scientific language (Cavagnetto 2011: 34; Jiménez-Aleixandre, Bugallo & Duschl 2000: 758; Lemke 1990: ix). While argumentation is commonly perceived as a combative interaction in which one side is ultimately victorious over another (Berland & Reiser 2008: 27), scientific argumentation is more complex; it is both competitive and collaborative in nature (Cavagnetto 2010: 337). There may be opposing evidence and ideas, but the pursuit of scientific knowledge is the enduring common goal (Berland & Reiser 2008: 27-28; Cavagnetto 2010: 337). The basis of any scientific argument are pieces of observable evidence which are then combined to formulate and assess ideas (Cavagnetto 2011: 34; Yore, Bisanz & Hand 2003: 691). In this respect, argumentation is a “strateg[y] for resolving [scientific] questions, issues, and disputes” (Jiménez-Aleixandre, Bugallo & Duschl 2000: 758). Argumentation is at the heart of the dynamic nature of science. Without it, science cannot be fully understood.

As a fundamental scientific practice, argumentation is also central to scientific literacy. A survey of science experts including researchers, science educators and science communicators reached five points of consensus regarding science competency for citizenship; among these were “critical attitude/thinking”, “ability to search for, analyze, synthesize and communicate information”, and the “ability to reason, analyze, interpret, and construct an argument in relation to scientific phenomena and knowledge” (Blanco-López et al. 2015: 181). Not only is argument mentioned explicitly, but the other aspects are tightly intertwined with argumentation, which necessarily requires critical reasoning and reflection (Cavagnetto 2011: 35; Jiménez-Aleixandre, Bugallo & Duschl 2000: 757-758). These aspects are also emphasized in Austrian higher secondary curricula for biology. For instance, students are expected to differentiate between different types of argumentation (BMBWF 2015: 83; BMBWF 2018; BMBWF 2019: 5); collect information from various sources and interpret and judge their reliability (BMBWF 2015: 85, 87, 88; BMBWF 2018; BMBWF 2019: 85, 92); recognize and interpret assertions from different perspectives about controversial topics (BMBWF 2015: 83, 84, 85; BMBWF 2018; BMBWF 2019: 85, 97); and reflect on current scientific questions and challenges to formulate a justified position on the topic (BMBWF 2015: 8; BMBWF 2018; BMBWF 2019: 95).

Unfortunately, however, science teaching has typically neglected to address argumentation (Driver, Newton & Osborne 2000: 288). Although Cavagnetto (2010: 337) recognizes a steady increase in argument-based interventions in science education contexts over the last 30 years, argumentation is consistently a challenge for students of all ages (Moore 2019: 430; Norris & Phillips 1994: 950; Pessoa, Mitchell & Miller 2017: 42) and requires more attention. Yet, not only students struggle with argumentation. There is substantial variation in how argumentation can function in the classroom. Argumentative purpose and structure, level of language, mode of communication, and implementation possibilities are all factors to consider (Cavagnetto 2010: 340; Coffin 2009: 513-514; Moore 2019: 430), and teachers often lack the tools and/or confidence to support students' learning (Moore 2019: 430).

What does teaching argumentation entail? Cavagnetto (2010: 352) asserts that argument instruction cannot be reduced to teaching argument skills. Mere knowledge of argument structure, while important for scientific literacy, does not encompass the complex nature of science (ibid.). In the present endeavor to integrate Norris and Phillips' (2003) fundamental sense of and Roberts' (2007, 2011) Vision II orientation to scientific literacy, the role of language is considered essential in understanding the negotiation of scientific developments in the public sphere. The examination of argumentation can help students understand and acquire some of the more informal scientific processes, including practical, pragmatic and moral aspects (Jiménez-Aleixandre, Bugallo & Duschl 2000: 757-758). According to Zeidler and Sadler (2011: 181), functional scientific literacy includes argumentation used to advance the understanding of the human condition. This is consistent with Lemke's (1990: 129) view that interaction with various attitudes about science is integral to science teaching.

The study of argumentation is complex and diverse. Argumentation has been approached from philosophical, rhetorical, linguistic, and educational perspectives (Coffin 2004: 230), to name a few, and researchers from any of these perspectives may examine issues involving the production, analysis or evaluation of argumentative discourse (Eemeren et al. 1996: 12). An influential approach to the analysis, construction, and evaluation of argumentation in science and education has been Toulmin's model of argument (Coffin 2004: 520; Eemeren et al. 1996: 129; Erduran, Simon & Osborne 2004: 918; Jiménez-Aleixandre, Bugallo & Duschl 2000: 760). First published in 1958, Toulmin's *The Uses of Argument* challenges idealized logical models of argumentation as the only valid type. Toulmin emphasizes the importance and legitimacy of what he calls "justificatory" (Toulmin 2003: 12) or "substantial" arguments (Toulmin 2003: 105); what he considers to be argumentation in practice (Jiménez-Aleixandre, Bugallo & Duschl 2000: 760). Instead of a series of premises that already contain the conclusion, as in formal logic, substantial argumentation involves the assertion of a standpoint or claim which requires justification and content knowledge to understand (Eemeren et al. 1996: 132, 135; Jiménez-Aleixandre, Bugallo & Duschl 2000: 782; Toulmin 2003: 114-115). The strength of an argument depends on its potential to withstand criticism (Toulmin 2003: 8), the criteria for which are specific to the field of knowledge and community norms (Eemeren et al. 1996: 130).

The flexibility of Toulmin's model arises from his emphasis on a procedural interpretation of form (Eemeren et al. 1996: 135; Jiménez-Aleixandre, Bugallo & Duschl 2000: 760, 762). He identifies three core steps of argumentation, irrespective of discipline: claim, data and warrant. The claim expresses the opinion or assertion, which is defended by the data; the warrant acts as the justification for using the data to support the claim (Toulmin 2003: 92). The view of legitimate argumentation as a course of action with a generic but flexible structure has been shown to be useful as an analytical tool for investigating argumentation in science discourse (Carrion 2018: 314; Erduran, Simon & Osborne 2004: 918; Kelly 2010 [2007]: 453-454; Sadler & Zeidler 2004: 77). The Toulmin model poses some challenges, however. Determining what information counts as claim, data, warrant or any other step can be difficult and careful attention to contextualized use of language is necessary (Erduran, Simon & Osborne 2004: 918- 919). Indeed, even Toulmin acknowledges that relying on grammatical structures to identify the function of an utterance is insufficient, as a clause or sentence may have more than one purpose (Eemeren et al. 1996: 140). As the fundamental sense of scientific literacy and language in context are central to this analysis, a linguistic approach to argumentation similar to Toulmin's foundational model will be adopted (see section 5.2.4.)

4. GMO Infographics

4.1. Infographics: definition and types

A portmanteau of the phrase *information graphics* (Krum 2014: 6), the term *infographic* carries some ambiguity regarding its relation to other types of visualizations and its novelty, resulting in varying uses of the term. At their core, infographics are not original or unique. The origins of infographics go back to the Stone Age, long before mass communication, and include influential developments such as the use of graphs and charts to explain numeric data in the late 18th century, creation of the Isotype[2] pictorial method of representation in the 1930s, and the mass distribution through mainstream news publications during the second half of the 20th century (Smiciklas 2012: 8-9). It is during this latter phase, according to *Mirriam-Webster* (2019: s.v. *infographic*), that the portmanteau was coined (cf. Krum 2014: 6). While the social affordances of the internet have inaccurately created the perception of infographics as a 21st century innova-

[2] Developed in Vienna by Otto Neurath (Neurath 1936: 9; Smiciklas 2012: 9), the international system of typographic picture education, or Isotype, was an attempt to bridge language barriers and enrich the fields of education and advertisement by establishing rules for the use of pictures (Neurath 1936: 7-8, 13-14).

tion (Smiciklas 2012: 6), it is precisely modern technological advancements that lend contemporary infographics distinct qualities in comparison to other forms of visual communication.

The long and complex history of infographics makes it challenging to define them precisely. In basic terms, infographics are texts that present and communicate information visually (Krauss 2012: 10; Lankow, Ritchie & Crooks 2012: 20; Polman & Gebre 2015: 868). With this broad definition, anything involving graphic and information design, from a street sign to a magazine spread, could potentially be understood as an infographic. This is precisely how Lankow, Ritchie and Crooks (2012: 20) conceptualize infographics, stating that "[t]here is no threshold at which something 'becomes' an infographic". Occasionally, infographics are equated with data visualizations (e.g. Matrix & Hodson 2014: 17), yet this is seen by others as outdated and restrictive to representations of numerical values (Krum 2014: 2, 6)[3]. There appears to be some general agreement and acceptance that 'modern' infographics are more than simple visual representations of data. Krum (2014: 6), a data visualization and infographics designer, defines an infographic as "a larger graphic design that combines data visualizations, illustrations, text, and images together in a format that tells a complete story". Similarly, digital strategist Smiciklas (2012: 3) considers an infographic to be "a visualization of data or ideas that tries to convey complex information to an audience in a manner that can be quickly understood". According to both of these definitions, infographics are neither synonymous with data visualization nor are data visualizations an obligatory element.

The affordances of digital media have strongly influenced the contemporary understanding of infographics. Several authors refer to the role of desktop or web-based software in the creation of infographics (e.g. Krum 2014: 306-327; Matrix & Hodson 2014: 17; Smiciklas 2012: 175-178; Veszelszki 2014: 100). The internet as a modern communication and publishing tool has contributed to the

[3] Strictly speaking, the term *data visualization* need not exclude qualitative data; however, in the realm of graphic and information design, data is understood as quantitative (see Krum 2014: 2-6; Lankow, Ritchie & Crooks 2012: 19; Smiciklas 2012: 21-26).

notion of modern infographics as a predominantly digital text type, often considered an integral part of an online presence for digital media outlets and marketing companies (Davis & Quinn 2013: 16; Krum 2014: 58; Lankow, Ritchie & Crooks 2012: 31; Smiciklas 2012: 139-153). Moreover, the layout of websites has affected the perception of infographics today. In general, websites are designed to match the width of a browser window or screen and often contain content that extends beyond the bottom edge of the window. This facilitiates a long vertical orientation for infographics (Krum 2014: 58, 60), a format that for many became synonymous with the term (Lankow, Ritchie & Crooks 2012: 31). There are, of course, plenty of horizontal infographics as well; factors such as medium of publication may affect this choice. Indeed, with rapid digital advancements, the potential formats of infographics have evolved too, from traditional static images to zoomable and clickable infographics, which allow the reader to magnify information or view links for additional information, to animated and video infographics, which incorporate differing degrees of motion, to interactive infographics, in which variables can be manipulated by the viewer (Krum 2014: 31-50). Static infographics are the most common (Lankow, Ritchie & Crooks 2012: 60) and the type examined in this analysis.

For the purposes of this thesis, a contemporary perspective of infographics is adopted following Smiciklas' (2012) and Krum's (2014) approaches. Infographics are understood here as multimodal texts which may incorporate various constellations of verbal and visual resources and go beyond any single visualization of information. Furthermore, infographics are considered as standalone texts in which the constituent parts are not merely combined; they interact with each other to construct a cohesive presentation (Cmeciu, Manolache & Bardan 2016: 54; Krauss 2012: 10; Veszelszki 2014: 108). Better designed infographics incorporate the different elements in such a way to present a narrative (Krum 2014: 6; see also Krauss 2012: 10; Lindblom et al. 2016: 38). In doing so, infographics are more than displays of information; they present interpretations to the reader (Veszelszki 2014: 101).

The functions of infographics are almost as diverse as the content they may contain. Needless to say, all infographics aim to communicate some kind of information; it is motivating factors behind communicating that information that are consequential (Lankow, Ritchie & Crooks 2012: 38). Krum (2014: 6) considers the overarching purposes of infographics to resemble those of public speaking, namely "to inform, entertain, or persuade the audience" (ibid.). The purpose and audience, in turn, determine the infographic's priorities, of which Lankow, Ritchie & Crooks (2012: 38-39) identify three: comprehension, retention, and appeal. Cmeciu, Manolache and Bardan (2016: 54) argue that the aim of all infographics, whether explicitly or implicitly, is to convince the reader to act.

4.2. Infographics in educational settings

As an integral part of the digital landscape, infographics deserve consideration as educational resources to support the development of pluriliteracies (see section 2.3.). The use of infographics in teaching, both generally and specifically for science, is a relatively new area of research (Matrix & Hodson 2014: 18; Polman & Gebre 2015: 875); however, there is accumulating support for incorporating infographics as part of a well-rounded repertoire of teaching materials. Both the multimodal nature of infographics and links to fields outside can help students engage with science content in a way that supports a notion of scientific literacy that aims to cultivate competent citizens.

The visual nature of infographics is frequently cited as effective in supporting science learning. This pertains partially to the understanding that visual representations are an integral part of the language of science (see section 3.5.2.1). Because they involve the synthesis of various elements, infographics can be considered to be meta-representations of scientific representations (Polman & Gebre 2015: 871), which show the relationship between general scientific ideas and real-world phenomena. Apart from that, visualizations appeal to and engage, what is at least culturally considered to be, our most dominant sense (Krum 2014: 14-15; Smiciklas 2012: 7; cf. Hutmacher 2019: 6-9). While the exclusive importance of visual processing may be somewhat overstated (Hutmacher 2019: 10), the multimodal nature of infographics provides opportunities for student engagement. As a part of diverse set of materials, comparing and contrasting infographics with other forms of representations reinforces engagement with the content (Lamb & Johnson 2014: 54; Polman & Gebre 2015: 872). Students also tend to be drawn to infographics; an investigation of learners' experiences with infographics found that students felt strongly that visuals in infographics supported their learning process (Yıldırım 2016: 101) and preferred infographics to plain text documents (Yıldırım 2016: 102-103). There is an important difference to be made between preference and how one actually learns, but generating student interest is half the battle.

As a form of popular science, infographics have great potential to connect with students. Just as their visual nature can be motivating for students and support learning processes, so can their status as authentic texts encourage engagement and stimulate deep learning. In particular, infographics can be one way to establish personal relevance of science knowledge often lacking in science classrooms (Polman et al. 2014: 799). Infographics have emerged as a new form of data journalism used to convey the relevance of complex science to society (Lamb et al. 2013: 25; Polman & Gebre 2015: 871) by incorporating norms from and creating connections with other domains and communities (Lamb & Johnson 2014: 55-56; Polman & Gebre 2015: 872). This reflects a wider move in science communication, as well as other areas, to engage with the general public in context-specific ways (Polman & Gebre 2015: 871; Cmeciu, Manolache & Bardan 2016: 54-55), which carries the advantage of promoting discussion and conversation (Cmeciu, Manolache & Bardan 2016: 55; Jarman & McClune 2007: 9). There is, however, a common concern about authorship, reliability of information, and quality of infographics (Lankow, Ritchie & Crooks 2012: 31; Polman & Gebre 2015: 874, 878-887), even among students (Yıldırım 2016: 101). While this is a legitimate concern, these are aspects which can and should be addressed in the classroom (Davis & Quinn 2013: 17-18). Whether well- researched or not, designed by professional or amateurs, infographics can be found in large quantities online via a simple image search or reproduced on many websites (Cmeciu, Manolache & Bardan 2016: 55; Lamb & Johnson 2014: 54, 55; Polman et al. 2014: 782). In other words, the infographics that students encounter online may vary significantly in quality. Incorporating such examples in the classroom would contribute to their ecological validity (cf. Brossard 2013: 14098; Polman & Gebre 2015: 872).

Regarding scientific content and scientific literacy specifically, there are compelling claims about the potential of infographics to address scientific literacy. Although 'just' a type of text, infographics by all means can be integral to inquiry-based learning, a concept strongly emphasized in modern education. First, infographics can act as a springboard for various lines of investigation (Davis & Quinn 2013: 17-18; Lamb & Johnson 2014: 54). This may be, for example, an investigation into the reliability and verity of the information, as noted briefly above; an examination of the infographic's purpose and how the author fulfills this purpose; or a survey of scientific, political, social, or economic standpoints and their mutual influence on each other.

4.3. Genetically modified organisms

Infographics is a medium which one can use as a starting point to explore a plethora of socio-scientific topics, from vaccinations to climate change to genetic engineering. It is this latter area of research, specifically genetically modified organisms (GMOs), that provides the socio-scientific context for the analysis.

Genetic engineering is a process by which biological and technological techniques are employed to change the genetic makeup of an organism. Any organism that undergoes this process is called a genetically modified organism (GMO). Genetic engineering plays a significant role both in biomedical research and agriculture (Regenass-Klotz 2005: 73-144), fundamentally changing how potential challenges in either of these areas are addressed. Although plants or animals can be genetically modified, the abbreviation GMO usually refers to plants.

In every cell of every organism there are long molecules called deoxyribonucleic acid, known as DNA, which contain the genetic code. Simply put, DNA contains information that determines how an organism functions and looks. An alternation in the genetic code can result in a change in physiological or physical traits. Spontaneous or uncontrolled changes are called mutations, and can vary in origin, scale and effect. Mutations are typically associated with negative consequences, yet they can also result in positive developments, which, if passed on to subsequent generations, may become the norm.

Humans have long taken advantage of plant mutations, choosing individuals with desired characteristics for reproduction in the hope that the subsequent generation will exhibit these traits. In doing this, certain pieces of DNA have been selected for survival; the genetic code that leads to the desired attributes are passed on to subsequent generations. It is through this process of artificial selection that we have today's cultivated plants: corn, wheat, broccoli, apples, etc. as they are presently known, in both their physical and physiological composition, would not exist without direct human intervention. (Kempken & Kempken 2012: 1-12). Genetic engineering is a modern form of trait selection, yet one that is wrought with complexity and controversy. Terms like *genetic engineering* and *GMO* can trigger a broad spectrum of feelings and opinions, from awe to fear to confusion.

Genetic engineering has been around since the 1970s, when it was discovered that it was possible to take DNA from different sources, slice it, and recombine the resulting fragments to create new functioning DNA molecules (Regenass-Klotz 2005: 73). In 1980, the first bacterial DNA was inserted into plants (Kempken & Kempken 2012: 14). Since then, researchers have explored ways to genetically modify plants to make them more resistant to their environments (whether ecological stress, e.g. drought; or anthropogenic stress, e.g. herbicide use), to improve their nutritional content, and to produce new raw materials for commodities like vaccines and fuels (see Kempken & Kempken 2012: 135-191).

In addition to the broad spectrum of potential benefits, there are wide-ranging concerns about GMOs and any possible effects they may have, providing an opportunity to explore several socio-scientific issues. Soon after their commercialization in the 1990s, movements against the technology emerged (Clark, Ryan & Kerr 2014: 177). On the one hand, concerns about GMOs are ecological; for example, the transfer of modified DNA via pollen to non-modified species, the uncontrolled spread of the GMO in the ecosystem, or possible negative effects that toxins produced by the GMOs (for instance, if the GMO was modified to produce insecticide against pests) may have on non-targeted fauna (Kempken & Kempken 2012: 224-230). Issues of human health are also at the forefront. This includes questions concerning the extent to which GMOs may induce allergic reactions in humans, whether antibiotic resistance could be transferred to microorganisms that are pathogenic to humans, and additional concerns about unwanted and unforeseen toxic effects (Kempken & Kempken 2012: 230-238).

Although the majority of issues cited as arguments against genetic modification are considered to be low-risk, if not negligible, especially when it comes to human health (e.g. Kempken & Kempken 2012: 223, 223-224, 231, 233), this does not mean that these concerns are to be dismissed. A significant problem is how the debate surrounding GMOs is characterized and carried out. The lack of effective communication and trust between parties involved are big obstacles for laypeople trying to make informed decisions (Kempken & Kempken 2012: 219).

One aspect of this obstacle is the conceptualization of risk. When it comes to GMOs, scientists and non-experts tend to hold diverging assumptions as to what may be considered a risk (Kempken & Kempken 2012: 2019). Indeed, any assessment of risk is inherently subjective, as it is context-dependent (ibid.). A scientist investigating ecological issues will therefore approach risk differently than a human health researcher. Likewise, a farmer will generally see risk differently than scientists in the field or a suburban parent.

Perhaps the most significant hurdles to effective communication are polarized characterizations of GMOs and those who support or criticize them. Just as there is no unified concept of risk, there is also no unified concept of GMOs.

However, the characterization of biotechnology in public debates tends to be dominated by either a “rhetoric of hope” or a “rhetoric of fear” (Hellsten 2002: 459), the latter of which is prominent in GMO debates (ibid.). The metaphorical language often used to communicate issues, while effective, can also obscure the connections between science, politics and other social aspects (Hellsten 2002: 460). There is no single type of genetic modification (Biddle 2018: 362-363; Kempken & Kempken 2012: 219-220); the desired trait, type of modification, and effects are different for each case. Consequently, “any attempt to evaluate such crops as a class is doomed to fail” (Biddle 2018: 362).

In a similar vein, generalizations of GMO critics are similarly unproductive. Often referred to as “ignorant” (Biddle 2018: 362) or “irrational” (Bloomfield & Doolin 2012: 520) for rejecting GMOs, critics are unfairly stereotyped. The difference in values and therefore risk assessment (see above) is rarely acknowledged in public debates. Critics may not understand the heterogeneity of GMOs and their effects, but outright rejection of their concerns only serves to further compound problems within science communication (Bloomfield & Doolin 2012: 520). In looking at argumentation in GMO infographics, the following analysis acknowledges the different perspectives that may influence scientific issues.

5. Methodology

5.1. Research aims and questions

The following analysis of GMO infographics aims to explore a way of supporting the development of scientific literacy that operationalizes the integration of content and language (see chapter 2). Specifically, this investigation considers the role argumentation plays in the construction of scientific knowledge in the public sphere by examining how perspectives on GMOs, a multifaceted controversial topic, are expressed in infographics that explicitly incorporate more than one point of view. The intent is not to judge the quality or effectiveness of the infographics themselves, but rather to implement frameworks that allow a systematic description of the texts at hand. The objective in doing so is to identify the patterns of meaning authors create, revealing the functional connection between the semiotic resources used and the meanings they express.

Static infographics like the ones examined here use verbal and visual modes to communicate meaning. This raises questions surrounding which tools are appropriate and effective for providing such a description. A social semiotic approach to language, Systemic Functional Linguistics (SFL), acts as the starting point for the analysis, emphasizing the social dimension of communication, bridging language and content. Developments have been made within SFL to describe visual meaning-making, as well. However, in keeping with the aim of advocating interaction between conventionally separated fields, a framework from information design is also incorporated into the analysis. The frameworks are explained in detail below. The first research question arises from applying these frameworks, namely: to what extent do the applied frameworks work together to describe meaning-making in the infographics?

Using these frameworks, the extent to which these instances of argumentation are expressed linguistically or verbally is explored. Of particular interest in this analysis is the way in which authors organize information in the infographics and express attitudes to construct a stance on GMOs. With which semiotic resources do authors scaffold and organize their argumentation (in other words, how do they create textual meaning)? With which semiotic resources do they express attitudes (how do they create interpersonal meaning? In answering these questions, an explanation can be made regarding how the authors use textual and interpersonal meanings to construct a stance on GMOs.

Finally, in concordance with the overarching aim of this analysis, the relevance of these questions to educational settings will be discussed. The focus of this section will be to consider how an awareness of the use of these semiotic resources in science infographics can enrich a CLIL science curriculum.

5.2. Conceptual framework

As previously mentioned, social semiotic theory provides the framework and most of the tools for the present analysis. Specifically, the principles of Systemic Functional Linguistics (SFL) are employed to identify the presence of argumentation and to examine how language is used to fulfill this function. The following sections will explain the main tenets of SFL, introduce the specific aspects of SFL relevant to both verbal and visual aspects of this analysis, and clarify SFL's relevance to pedagogy and CLIL.

5.2.1. Systemic Functional Linguistics (SFL): introduction

There is a strong case to be made for selecting the theory and tools of SFL to ground and carry out this analysis. It is a flexible framework that has been applied to a myriad of contexts, some of which are directly relevant to the concepts discussed here.

Developed by social semiotic linguist Michael Halliday in the 1960s, SFL works off of the assumption that meaning-making is a process through which meaning-making resources and contexts influence each other reciprocally (Schleppegrell 2012: 21). SFL has been called an "appliable kind of linguistics" (Matthiessen 2012: 436), blurring the lines between theoretical and applied linguistics (Halliday & Hasan 2006: 27; Matthiessen 2012: 436-437). Deeply embedded in SFL are notions of ideology. All texts are viewed as consciously or unconsciously motivated by our attitudes, values, and beliefs (Eggins 2004: 10; Martin & Rose 2007: 314). The functional and sociocultural focus of SFL make it an appropriate theoretical starting point for examining how meanings around controversial scientific developments are negotiated.

SFL has a notably long and close association with pedagogical contexts. Since the beginning of its development, teaching has occupied a central focus in SFL theory (McCabe 2017: 592). Literacy issues in particular have received considerable attention by SFL scholars (Dalton-Puffer 2013: 225; Morton & Llinares 2017: 6; Oteíza 2017: 459). Instruction that draws on SFL principles is characterized by an explicit focus on language choice (Pessoa, Mitchell & Miller 2017: 42), which consequently equips teachers and students with tools for the analysis and production of relevant genres (Forey & Polias 2017: 149; Pessoa, Mitchell & Miller 2017: 42).

SFL has been proposed as an approach that offers beneficial insights and tools for CLIL instruction. Central to these arguments are the tight connections established in SFL between language and context, which corresponds to CLIL's objective of transcending the conventional boundaries between language and content learning (Coffin 2017: 91; Llinares 2015: 62-63, 68-69; Meyer et al. 2015: 45). Coffin (2017: 91) comments that SFL's "architecture, history and research community make it strategically positioned" to respond to questions concerning the interaction of language and content – precisely what the pluriliteracies model aspires to address (see section 2.3.). To do this, the role of language needs to be promoted (ECML 2019), for without language there is no learning. Language is the primary way in which knowledge and understanding are demonstrated, and through which learner progress is expressed (Meyer, Halbach & Coyle 2015: 5).

5.2.2. Basic concepts of SFL

SFL considers the structure of language, as one of our primary resources for making meaning, intricately linked with social function and context (Eggins 2004: 3). Any instance of language is considered purposeful, and the general purpose of language is to make meaning (ibid.). Consequently, the functional use of language greatly influences if not determines its structure; in the words of Halliday (1994: xviii), "grammatical patterns […] bear a natural relation to the meanings they have evolved to express". This differentiates SFL from traditional formal approaches in that the central concern is how meaning is expressed, as opposed to what forms of language convey what meaning (Halliday 1994: xiv).

The systemic aspect of SFL deals with the conceptualization of linguistic resources as an intricate network of dynamic and open systems which express meaning potential (Anderson 2013: 279; Schleppegrell 2012: 22). There are three main features of a semiotic system: there are a finite set of choices, the choices are discrete, and the discrepancy between the choices carries meaning (Eggins 2004: 13). Choice in this context does not refer to a conscious decision on the part of the language user, but a set of either-or alternatives available under the existing conditions (Eggins 2004: 20; Halliday 1994: xxvi). Analysis of such language choices exposes variation in the construction of content, role relationships and information flow (Schleppegrell 2012: 22), the combination of which constructs the meaning of a given utterance.

According to SFL, there are three general functions of language, termed metafunctions, in any given social context. These three types of meaning are illustrated in Figure 3a. The ideational metafunction construes experience; who is doing what, where, and when. Social relationships, opinions and feelings, either regarding the audience or the content of our utterances, are expressed by the interpersonal metafunction. The ideational and interpersonal metafunctions are connected through the textual metafunction, which creates relevance to the context and is responsible for information flow. Integral to SFL is the idea that these general meanings are simultaneously constructed in every utterance (Eggins 2004: 3; Martin & Rose 2007: 7). From an analysis standpoint, the metafunctions can be regarded as "complementary lenses" through which language can be interpreted (Martin & White 2005: 7).

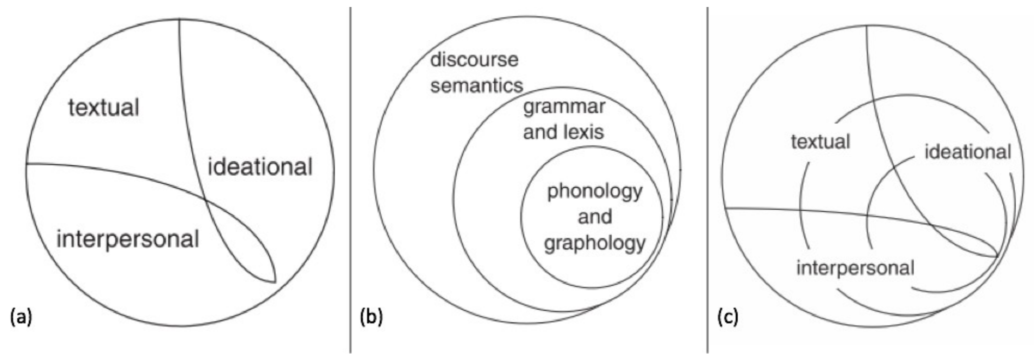

Figure 3. Visual representation of (a) SFL's three metafunctions, (b) three levels of coding meaning, and (c) the intersection of metafunctions and language strata (Martin & White 2005: 8, 9, 12).

Moreover, each of these metafunctions are present on multiple levels, or strata, of language. Represented by concentric circles in Figure 3b, each level of language involves reinterpretation and metaredundancy; in other words, the patterns of one level contribute to the patterns of the next level (Martin & Rose 2008: 10, 30). The larger the circle, the greater level of abstraction. The sounds we make (phonology) and the written representation of those sounds (graphology) can be make meaning on their own, but get recoded as grammar and lexis, also referred to as lexicogrammar (Martin & White 2005: 8-9). This, in turn, is recoded as discourse semantics, linguistic texts with meaning beyond the clause (Martin & White 2005: 9). Taking a top-down perspective, texts are realized through lexicogrammar, which are realized through either phonology or graphology (Eggins 2004: 19). Each metafunction contains semiotic systems, or networks of options, moving from general to specific features, at each level of realization (Halliday 1994: xiv) (Figure 3c). These systems provide relevant concepts and tools to explore these types of meanings and their nuances (Schleppegrell 2012: 21).

5.2.3. Language in context: SFL notions of register and genre

As previously mentioned, SFL considers manifestations of language inseparable from context and culture. The theoretical concepts of language stratification and metafunctions belong to SFL's "internal model of language function" (Martin & White 2005: 26). However, SFL has also developed an "external model of language use" (Martin & White 2005: 27) involving stratification of social context into two levels, register and genre, as seen in Figure 4.

Register describes language in relation to a particular situation. While the strata of phonology/graphology, lexicogrammar, and discourse semantics portray language organized by metafunction, register represents the situational context organized by metafunction (Martin & Rose 2007: 297). The ideational, interpersonal, and textual metafunctions encode the three functional dimensions of register, known as field, tenor, and mode (Martin & Rose 2008: 11). Field is concerned with the activities and participants in the discourse; tenor deals with relationships between interactants; and mode is concerned with the role of language (Martin & Rose 2007: 296; Rose 2012: 2010). Field, tenor, and mode can be considered to be resources for generalizing patterns of ideational, interpersonal, and textual meaning, respectively, across different genres (Martin & Rose 2007: 297-298).

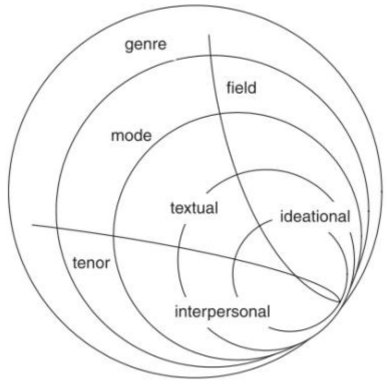

Figure 4. Stratification of social context (genre and register) within which language is stratified. Register is comprised of three variables (field, mode, and tenor), corresponding to the three metafunctions (Martin & White 2005: 32).

There are various theoretical approaches to genre across various disciplines, but SFL has a very specific approach to its conceptualization. Within the model of social context, genre represents cultural context. It is defined as "a staged goal-oriented social process" (Martin 2009: 13): staged, because it is generally impossible to achieve goals in one step; goal-oriented, because we use genres to make things happen and a lack of completion leads to frustration; and, echoing the central tenet of SFL, social, because texts are constructed for social purposes (ibid.; see also Martin & Rose 2007: 8; Martin & Rose 2008: 6). One can identify four broad categories of genre based on their general social purpose and literacy teaching focus: story genres, informing genres, procedural genres, and evaluating genres (Rose 2012: 211-212). A text may fulfill multiple purposes and genres may seem to overlap, but the frequent occurrence of configurations of meanings that perform a certain cultural purpose will reflect the text's primary goal (Martin & Rose 2007: 261; Rose 2012: 209, 211). These "relatively stable components of [the genre's] organization, recognizable in some form or another" (Martin & Rose 2007: 10) are called stages. Less stable are the phases within each stage, the presence, prevalence and order of which may vary as they are situation- specific and responsible for expressing register (Rose 2007: 187).

5.2.4. Argumentation in SFL

According to Rose's (2012: 212) depiction of genre families, evaluating genres, specifically argumentation[4], are of interest here. As a genre, argumentation is a social negotiation of stance (Rose 2012: 219), in which the goal is to evaluate positions (Rose 2012: 211) and present a view persuasive to others (Pessoa 2017: 77). The notion of argumentation in SFL has much in common with Toulmin's model (see section 3.6.). Both approaches view argumentation as a discipline-nonspecific practice that can take on discipline- specific characteristics (Eemeren et al. 1996: 135-138; Martin & Rose 2008: 138, 167); both distinguish functional steps, obligatory as well as optional, that comprise argumentation (Coffin 2009: 235); and both have been widely applied to educational contexts (e.g. Berland & Reiser 2008; Coffin 2009; Erduran, Simon & Osborne 2004; Jiménez-Aleixandre, Bugallo & Duschl 2000; Moore 2019; Pessoa 2017). An important difference between Toulmin's foundational model and SFL's approach to argumentation, aside from the linguistic focus, is the affordance of describing more than one perspective and even more flexibility with staging (Coffin 2004: 235).

In SFL, texts that perform argumentation can be characterized as being organized around internal cause and "text time" (Martin & Rose 2008: 118); in other words, the meaning of the text develops in relation to other parts of the text instead of external events (as is the case with telling a story, for example). There are three types of argumentation (Martin & Rose 2008: 118-122). One-sided arguments include expositions, in which a position is presented and argued for, and challenges, in which a position is presented and argued against. The third type of argumentation, discussion, is multi-sided and the focus of this analysis.

Discussions explicitly put forward and examine more than one side of a controversial issue. Martin and Rose (2007: 137) identify three stages that are

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[4] The terms *argument* and *argumentation* are often used interchangeably. Whereas Toulmin (2003) refers to *argument,* Eemeren et al. (2006) choose *argumentation.* Even in SFL genre literature, the terminology can be inconsistent; both terms are used to describe the genre, but only *argument* describes a stage of exposition (cf. Martin & Rose 2007: 113; Martin & Rose 2008: 118; Rose 2012: 211, 212, 219). For clarity's sake, *argumentation* will be used here to refer to the genre itself.

consistent elements of discussion genres: the Issue stage presents the question to be discussed; the Sides stage deals with two or more points of view on the subject; and the Resolution stage expresses the author's final position or judgement. In most cases, the staging occurs in that order, [Issue^Sides^Resolution][5]. Although the genre's schematic staging conveys an impartial and balanced handling of the topic, one position is often promoted more than others, moving the discussion clearly in one direction (Martin & Rose 2007: 121). Both the Sides and Resolution stages may contain additional phases. Sides may be supported by various claims (Claims phase), which, in turn, may be supported by various pieces of evidence (Evidence phase) (Coffin 2009: 519). Additionally, the Resolution may be accompanied by a suggestion for further action, a phase called Recommendation. These stages and phases serve as the canvases and subcanvases upon which the analysis is carried out.

5.2.5. Text in context: discourse semantics

Genre, in this case argumentation, acts as the frame of social activity within which instances of discourse are performed. Discourse analysis in the SFL tradition interacts with both the analysis of grammar and the analysis of social activity (Martin & Rose 2007: 4). Text, defined as "'any passage, spoken or written, of whatever length, that does form a unified whole'" (Halliday & Hasan 1976: 2 in Eggins 2004: 24), is considered the unit of discourse analysis in SFL (Schleppegrell 2012: 24). Discourse analysis investigates the means by which the text creates its meaning (Schleppegrell 2012: 22).

Discourse semantics deals with meaning made though language above the clause level. The semiotic systems on this level of language are known as discourse systems, which are sets of meanings that perform a particular metafunction (Martin & Rose 2007: 7). Despite the interactive relationship between grammar and discourse, the grammatical systems originally developed by Halliday, while

[5] Following the orthographic conventions used in Martin and Rose (2007), genre stages and phases are capitalized to distinguish the SFL-specific labels from the common use of the terms. The sequence notation consists of the sequential listing of phases and stages which are separated by a carrot symbol (^) and enclosed in square brackets.

valuable, are “not sufficient in themselves for analyzing how texts make meaning, or for teaching learners how they mean” (Rose 2006: 55). Martin and Rose have described six discourse systems, each a set of resources for making meaning. Periodicity and Identification convey different aspects of textual meaning, Ideation and Conjunction deal with ideational meanings, and Appraisal and Negotiation contain resources for expressing interpersonal meanings[6]. For the purposes of this analysis, the systems of Periodicity and Appraisal are selected for analysis based on their relevance to the research questions (section 5.1.)

The resources of Periodicity convey textual meaning by organizing the flow of information in a text. Framing and the traditional organization of texts into introduction, body, and conclusion are examples of Periodicity resources at work (Martin & Rose 2007: 187, 188). The role of expectation is central in how meaning is arranged through Periodicity. Discourse creates expectations by signaling what will follow and consolidates them by summarizing back (Martin & Rose 2007: 189). A wave metaphor is often used to illustrate the relationship between expectation and the resulting patterns of meaning, “in which moments of framing represent a peak of textual prominence, followed by a trough of lesser prominence” (Martin & Rose 2007: 189). As waves of information rise and fall, they develop a rhythm and flow together to form bigger waves, creating hierarchy of messages (Martin & Rose 2007: 188).

At the clause level, there are two overlapping waves involved in creating meaning: the Theme at the beginning of the clause, and the New[7] at the end (Martin & Rose 2007: 192). Halliday (1985: 39 in Eggins 2004: 275) defines Theme as “the element which serves as ‘the starting-point for the message: it is what the clause is going to be about’”. The latter part of the clause, the New, provides the additional information that helps develop the text further (Martin & Rose 2007: 192). Reiteration of similar choices of Theme and New work together to package

[6] Discourse systems, while not consistently capitalized in SFL literature, are capitalized here to clearly distinguish them as SFL constructs. The same will follow for key aspects of each discourse system.
[7] Martin & Rose (2007) use the term *New* where Halliday and Eggins use *Rheme* (e.g. Eggins 2004).

discourse as phases of information (ibid.).

Moving beyond the clause, at the discourse level, larger waves of information are of interest. Periodicity, instead of grammar, acts as the "packaging device" (Martin & Rose 2007: 212) for information. Patterns of Theme and New merge to create what are called *hyperThemes* and *hyperNews* or, beyond that, *macroThemes* and *macroNews* (Martin & Rose 2007: 193-199). Such higher-order Themes create expectations about distinct phases of text, as illustrated in Figure 5; in other words, they guide the text's development, which itself is influenced by the staging of the genre in question. In written texts, hyperThemes function at the paragraph level, where they predict the role of sentences in the paragraph (Martin & Rose 2007: 196), and macroThemes create expectations about whole paragraphs and larger chunks of text (Martin & Rose 2007: 197). The hyper- or macroNews look back on the development of the respective phases and develop ideational meanings. The number of layers is determined by the complexity of the text. Without these patterns of information, texts can be difficult to understand.

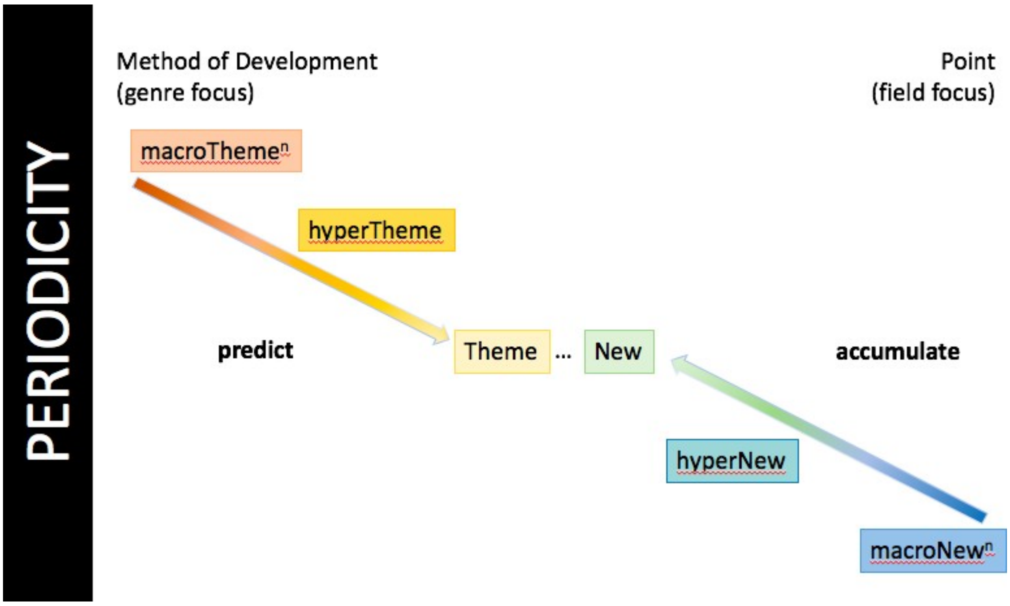

Figure 5: Layers of Theme and News in discourse (Martin & Rose 2007: 199). Higher-order macroThemes predict hyperThemes, which, in turn, predict the Themes of individual clauses. The patterns of information create a scaffold for the genre. Instances of News accumulate and are packaged as hyperNews and macroNews, which expand on the text's ideational meanings (field).

The second discourse system addressed here is Appraisal. Appraisal offers resources for expressing interpersonal meaning, specifically evaluation, attitude and emotion. Three interacting domains comprise Appraisal, shown in Figure 6. Attitude expresses feelings towards, reactions to, and evaluations of behavior and things; Engagement allows other voices to be brought into the discourse and communicates the author's position to these voices; and Graduation is concerned with the scale or degree to which Attitude is articulated (Martin & White 2005: 35-37). Resources from each of these domains can be implemented simultaneously, symbolized by curved brackets (Figure 6). Attitude, as the central element of this system (Martin & White 2005: 39), is given the most consideration.

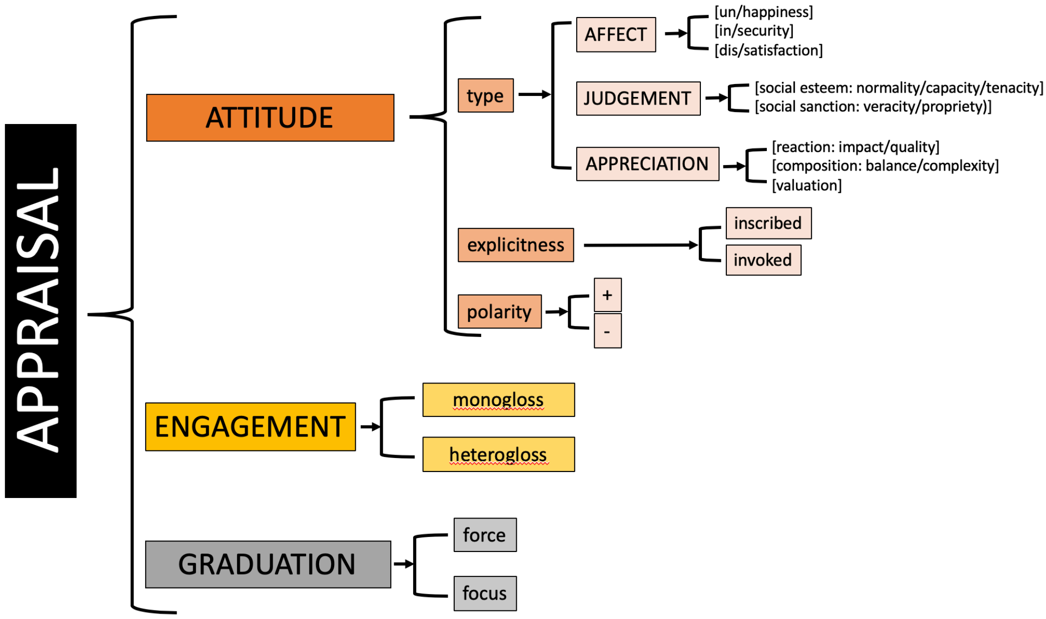

Figure 6: The Appraisal system according to Martin and White (2005).

Attitude is further divided into three parallel domains: type, explicitness, and polarity, each of which contains either/or choices. The main types of Attitude are AFFECT[8], which generally describes emotional reactions and states; JUDGEMENT, which expresses opinions about behavior relative to various normative principles; and APPRECIATION, which construes values about phenomena or things

[8] Attitude types are written in all caps following the conventions used in Martin and White (2005). Additionally, this serves to differentiate the attitude types from the discourse systems.

(Martin & White 2005: 25-26). JUDGEMENT and APPRECIATION can be understood as "institutionalised feelings" (Martin & White 2005: 45), dependent on shared values and beliefs. Each of these attitude types contain more specified categorizations, enclosed in square brackets (Figure 6). The examples below briefly illustrate the main attitude types, polarity, and the difference between inscribe and invoked attitude (for more examples see Martin & White 2005: 51, 53, 56):

(1) She worried time would run out.

(2) The library staff is thankful for the generous donation.

(3) According to Sarah, they are all idiots.

(4) The students rolled their eyes as the teacher passed out worksheets.

In (1) and (2) we see examples of negative and positive AFFECT, respectively. The verb *worried* expresses a feeling of [insecurity] on behalf of the subject *she* in (1), while in (2), the adjective *thankful* conveys a type of [happiness] felt by library staff. Additionally, (2) exhibits positive APPRECIATION [valuation]: the donation is appraised as something *generous*, and therefore of value. The JUDGEMENT in (3) and (4) is expressed in different ways. In (3), *idiots*, a noun with negative connotations, explicitly communicates, or inscribes, negative JUDGEMENT [social esteem: capacity] towards whomever *they* are. The same type of attitude, JUDGEMENT [social esteem: capacity], is expressed in (4) through *rolled their eyes*; however, in this case the Attitude is invoked. This example also illustrates the importance of context in interpretations of Appraisal. Without further context, one could understand the JUDGEMENT in two ways: the students' behavior as a negative evaluation of the teacher, or the author's negative opinion of the students' behavior. Alternatively, the action of eye rolling could be interpreted as boredom, and therefore negative APPRECIATION [reaction: impact] felt by the students regarding the classroom situation.

Attitude types are represented as a paradigmatic system (represented by an open square bracket in Figure 6); in other words, either AFFECT or JUDGEMENT or APPRECIATION is expressed by an utterance. This representation can be misleading, however. First of all, explicit attitudinal lexis is not always responsible for expressing our thoughts and feelings; even ideational meanings can invoke attitude (Martin & White 2005: 62). The four examples above illustrate how realizations of Attitude can be lexicogrammatically diverse (Martin & White 2005: 10), although they show only a fraction of the possibilities. Not only can verbs, nouns, adjectives and adverbs individually convey evaluation, so can various combinations of assorted grammatical categories. As a result, it can be challenging to differentiate between attitude types. Identifying invoked attitude, therefore, requires careful consideration of the context.

Furthermore, Martin and White (2005: 61) recognize the possibility of "hybrid realisations", utterances which may inscribe one type of attitude while simultaneously invoking another type (Martin & White 2005: 67). For example, positive APPRECIATION of an individual's work, such as in *creative artistic composition* [valuation], may also, depending on other contextual clues, be an implicit positive JUDGEMENT of the person themselves [social esteem: capacity].

Resources of Engagement and Graduation give nuance to attitudinal values. Engagement describes the potential for interaction with other voices. If such interaction occurs, this is called *heteroglossia* (Martin & White 2005: 92). This can be seen in example (3) above, where Sarah's voice is brought into the situation. Graduation resources strengthen or weaken attitudinal meanings as well as engagement values (Martin & White 2005: 135-136). There are two main types of Graduation, force and focus, both of which can be scaled up and down. Force deals with intensity and amount (for example, *generous* in example (2) above), while focus deals with prototypicality; the extent to which something belongs to a certain category (for example, *idiots* in example (3) above).

Altogether, the resources of Appraisal are responsible in establishing the overall tone or mood of the text (Martin & Rose 2007: 59). The patterns that emerge ultimately construct the stance of the author (ibid.). An inability to interpret attitudinal meaning in argumentation results in an inability to comprehend the author's position.

The systems of Periodicity and Appraisal express two types of meanings we want to look at in these texts. However, just as the ideational, interpersonal and textual metafunctions are at work in every text, so are the discourse systems that provide the resources to make these meanings. Although only two of the six discourse systems described by Martin and Rose (2007) are examined here, it is important to remember that not only do the other four contribute to the texts' meanings as well, but that the discourse systems interact with each other in constructing meanings (Martin & Rose 2007: 209). These discourse systems were constructed to describe particular linguistic resources for expressing meaning. Yet, infographics are known for their large share of visual elements. Any comprehensive analysis, therefore, requires "moving beyond linguistics into social semiotics" (Martin & Rose 2007: 321). The following section describes how SFL deals addresses multimodal texts and outlines the tools that will be applied to analyze the infographics.

5.2.6. Dealing with visuals

Since its inception, SFL has evolved to include practical descriptions of other semiotic resources, including images, sound, space, and action (Martin & Rose 2007: 321-322). As a functional semiotic theory with the capability to be expanded and modified in response to the changes in meaning-making potential that accompany new forms of communication, SFL affords substantial resources for describing the semiotic potential of contemporary multimodal texts (Unsworth 2006: 71). Despite the possibilities embedded within SFL, there are shortcomings in practice. The section below introduces the important influences from SFL as well as a framework from outside SFL that have shaped the analytical procedure for this investigation.

One of the most prominent developments in multimodality studies with origins in SFL comes from Kress and Leeuwen (2006), who recognized the growing importance of visual communication for the public (Kress & Leeuwen 2006: 3). In their construction of a "'grammar of visual design'" (Kress & Leeuwen 2006: 1), the authors do not claim to describe universal norms for meaning-making, rather, in accordance with SFL's emphasis on cultural context, they ground their framework within 'Western' culture (Kress & Leeuwen 2006: 4). Consequently, the assumption underlying this analysis is that the infographics are generally read left to right and top to bottom, although these two-dimensional multimodal texts may not be strictly linear.

Several aspects of this visual grammar can be problematic for this analysis, however. First, in presenting their visual semiotic systems, Kress and Leeuwen (2006: vii-viii, 41-21) consciously employ a distinct metalanguage to distinguish it from linguistic approaches. Such differences in terminology are not bad per se. Indeed, there is considerable concern that an over-reliance on linguistic theories to describe multimodal texts inhibits a comprehensive and adequate description of visual resources (Bateman 2018: 298; Lim 2018: 3). However, as suggested by Lim (2018: 3), it can be helpful to use consistent, if not familiar, nomenclature in educational contexts to facilitate learning.

Additionally, the systems described by Kress and Leeuwen (2006) do not provide adequate tools required to analyze infographics in the context of developing pluriliteracies. Kress has been criticized for representing modal affordances as mutually exclusive binaries (Prior 2005: 26); for example, that words are finite, sequential and vague while images are infinite, spatial and specific (ibid.). To equip students with the ability to understand and create multimodal science texts, one needs a more holistic approach that looks at the connections between modes (Unsworth 2006: 59). In an attempt to systematically examine the visual elements as they relate to the functions of Periodicity and Appraisal, two approaches are adopted; one from the field of information design and one developed within SFL.

5.2.6.1. The Richards-Engelhardt framework

The types of visual components that may be included in an infographic are diverse. From illustrations to graphs to vectors connecting various components, the selection of individual components and their constellations is tremendous. Yet, there are few frameworks that can cover all aspects or types of visualizations (Engelhardt & Richards 2018: 202). To address this gap, Engelhardt and Richards present their own framework, the “Richards-Engelhardt framework” (Engelhardt & Richards 2018: 202), in which they aim to offer “a systematic way to describe comprehensively the very broad design space of visualizations and the interrelationships between their constituents (Engelhardt & Richards 2018: 201).

Although the Richards-Engelhardt framework did not emerge from either a systemic functional or social semiotic perspective, the principles guiding the framework are still compatible with SFL constructs. Key to the framework is the notion of relationships; that any visual representation of information consists of multiple graphic components that interact with each other spatially to express meaning (Engelhardt & Richards 2018: 203-204). Particularly significant to the present analysis is the explicit recognition of words as graphic components in their own right (ibid.).

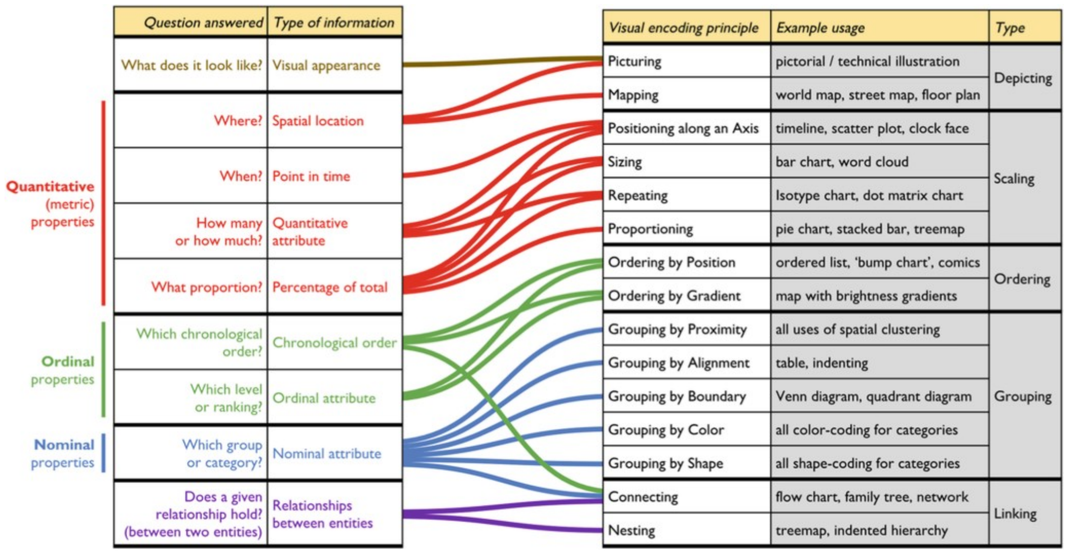

Figure 7: Interdependencies between types of information and the visual encoding principles according to the Richards-Engelhardt framework (Engelhardt & Richards 2018: 205).

The fundamental aspect of the Richards-Engelhardt framework are the modes of visual encoding, displayed in Figure 7. There are five main types of visual encoding: depicting, scaling, ordering, grouping and linking, listed at the far right of the figure. Each of these comprise at least two visual encoding principles, which in turn possess the potential to express one or more types of information, represented by the colored lines connecting the left and right sides of the diagram.

Engelhardt and Richards (2018: 208) additionally identify "modes of correspondence" and "modes of depiction" to further characterize visual encodings, but for the purposes of this analysis, only the modes and principles of visual encoding will be applied. In the interest of clarity, terms used from this framework will be enclosed in square brackets (e.g. [grouping by proximity]), adopting the notation from Martin and White's (2005) Appraisal framework.

The advantage of this framework is the ability to recognize several levels of meaning. Because graphic components can interact in different ways simultaneously, it is possible for several visual encoding principles to operate at the same time as well (Engelhardt & Richards 2018: 204). Consequently, the simultaneous expression of different types of meaning within visualizations can be described, complementing the SFL notion of metafunction.

The questions posed by Engelhardt and Richards as an aid to determine the relevant visual coding principles (see Figure 7) correspond broadly with Martin and Rose's system of Periodicity, as they address notions of packaging information. For example, as mentioned in section 5.2.5, the discourse system of Periodicity is traditionally used to describe the organization of a text according to paragraphs or groups of paragraphs. Paragraphs in the conventional sense are not present in infographics; visual encoding principles of grouping, however, form visual 'paragraphs' of information. Likewise, since infographics strive for a succinct presentation of information, it is expected that not all connections will be verbally explicit.

The framework provides less opportunities to describe visual notions of Appraisal. Any of the encoding principles have the potential to express interpersonal meanings (for example, a heart symbol could express positive AFFECT) but as a tool for primarily describing the organization of and relationships between graphic components, the framework does not provide a structured way to approach these meanings.

5.2.6.2. Visual appraisal

For a more organized approach to visual Appraisal, the social semiotic framework from Economou (2009) is adopted here. In her approach, Economou takes the Appraisal system outlined by Martin and White (2005) and adapts it to visual texts. Although all attitude types can be communicated visually (Economou 2009: 109), the system is not simply applied as is; rather differences in affordances of each mode are reflected upon and the system is tweaked accordingly.

One of the most significant differences between verbal and visual options for expressing Attitude is the degree to which attitudes can be expressed explicitly. Strategies for inscribing and invoking Attitude visually are shown in Figure 8. According to Economou (2009: 110), “the explicit inscription of attitude is [typically] limited in the visual in comparison with verbal text”. Depictions of embodied Attitude (facial expressions, for instance) can potentially inscribe Attitude, yet this is restricted to expressions of AFFECT, and even in this case, only few feelings or sensations can be expressed unambiguously (Economou 2009: 111). There are more possibilities for visually evoking Attitude, however. For example, visual realizations of lexical metaphors, such as an illustration of a crowded space to represent *packed like sardines,* or visual tokens, such as a rainbow, may implicitly express negative and positive attitudinal values, respectively.

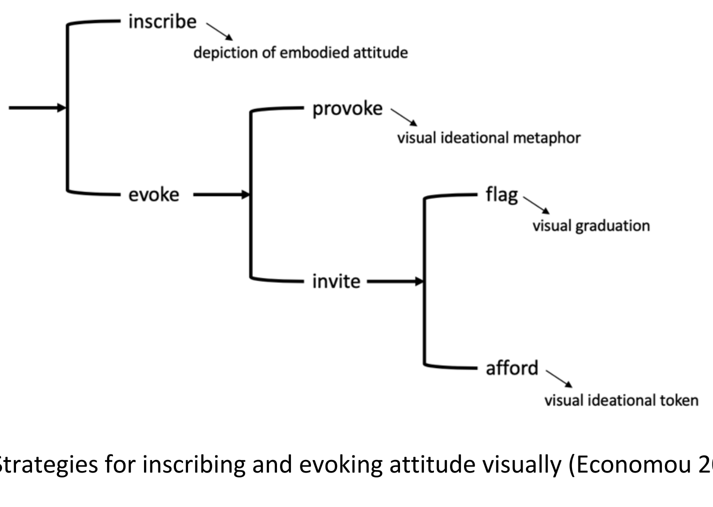

Figure 8: Strategies for inscribing and evoking attitude visually (Economou 2009: 109).

Graduation resources are a significant aspect of visual attitudinal expression. The way in which elements are presented can invite an evaluative reading of those elements, even if the token conveys no obvious attitudinal meaning on its own (Economou 2009: 156). The visual Graduation system according to Economou (2009: 163) is presented below in Figure 9. Both main types of Graduation, force and focus, are afforded by the visual system, and both of these can be scaled up or down. However, the visual system allows for simultaneous expression of force types (indicated by the curved brackets). Resources of visual focus deal with aspects like camera focus, sharpness and framing; aspects which have more relevance in photography and naturalistic images. Where Graduation is applicable in the images and illustrations of the infographics here, resources of force are relevant and therefore will be discussed in more detail below.

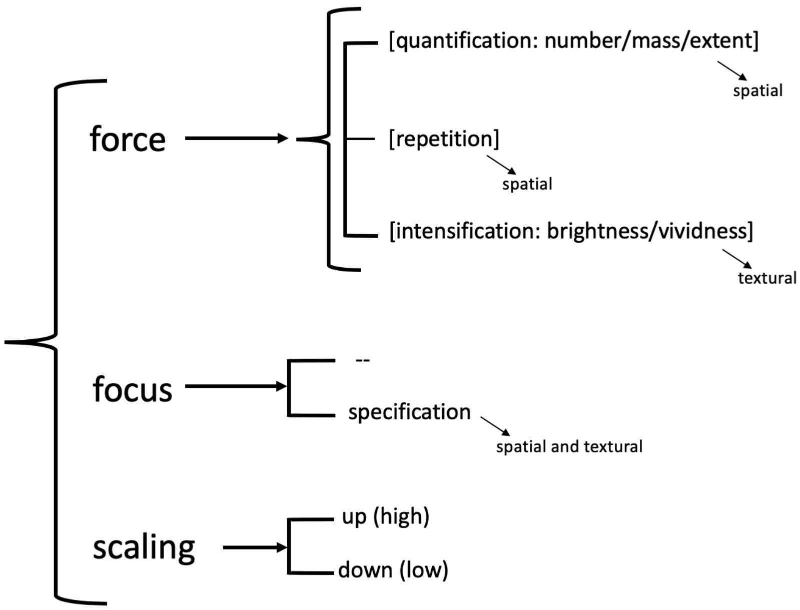

Figure 9: Basic options for visual graduation (Economou 2009: 163). In contrast with verbal Graduation, the system of visual Graduation offers more choices for force (double brackets) and fewer for focus ('missing' choices indicated by hyphens).

Force deals with the impact of an item, whether it serves to amplify or diminish a meaning. Visually, there are three types of force, [quantification], [repetition], and [intensification]. Values of [quantification] may show the size of something [mass], how many there are [number], or indicate the amount of space it takes up in the frame [extent]. The second type, [repetition], is realized by the presence of two or more visual elements that may inscribe or invoke attitude (Economou

2009: 169). This is not considered a separate option for verbal resources, where the repetition of lexis is considered a realization of [intensification] (Martin & Rose 2005: 20). Although [repetition] is similar to [quantification: number], Economou (2009: 169) considers there to be one important distinction between the two. Force is amplified by [quantification: number] when it is the number of items that provides meaning potential for some attitude value and not a single item alone. However, if the visual token evokes attitude on its own, the presence of more than one of these items serves to amplify the force of the attitude through [repetition]. Finally, in contrast to [quantification] and [repetition], [intensification] works texturally by shaping depth and structure through light, color hue, and saturation.

Visual graduation can evoke attitudinal meaning in visual elements that do not explicitly express interpersonal meaning. Just as in written language, the similarities and differences between various visual elements and between visual and verbal elements create patterns of meaning that influence how the text is read.

5.3. Data collection

Data collection was carried out through stratified sampling to ensure a sample useful for the analytical focus of this investigation (cf. Bateman, Wildfeuer & Hiippala 2017: 142). Infographics were selected from visual.ly, an online platform for data visualization used frequently as a source for infographics in research or cited as a possible source to find infographics for classroom use (e.g. Brown University 2014: 11; Davidson 2014: 39; Davis & Quinn 2013: 17; Dunlap & Lowenthal 2016: 46; Krauss 2012: 14; Krum 2014: 163-164; Lankow, Ritchie & Crooks 2012: 251; Polman & Gebre 2015: 876; Smiciklas 2012: 107; Veszelszki 2014: 100; Yildirim 2016: 99). First, content related to GMOs was selected by means of a tag search (https://visual.ly/tag/gmo), and the resulting content filtered for static infographics using the website's built-in filter; this resulted in 26 items. The following two criteria were subsequently applied to the results to produce a preliminary data set: the infographic must be published in English and the content must overwhelmingly deal with GMOs (i.e. GMOs must be the main topic of the text and not limited to a subsection or a passing reference). Five infographics were excluded for those reasons. Two additional texts were subsequently excluded on the basis of incompleteness (i.e. the preview image of the text showed more than what was ultimately available).

The remaining 19 infographics were examined for the occurrence of argument using the stages defined by Martin and Rose (2008: 121-122, 137). Due to the dynamic nature of infographics and relative lack of representational norms (Polman & Gebre 2015: 871), the presence of verbal or visual features that fulfilled the purpose of the respective stages was considered sufficient to identify the genre. The order of their occurrence was not a factor in determining their genre status, however. Ultimately, 17 texts were identified as manifestations of argumentation, three of which are discussions.

The three discussion texts were classified as such on the ground that they perform the functions described by the stages of the discussion genre, [Issue^Sides^Resolution]. Each of these can vary in length. Issue stages are recognized as introductions to the topic. For GMOs, this may include explanation of what they are and why the topic is relevant; however, this may also just be a short statement indicating the existence of a controversy. The Sides must exhibit a clear demarcation between different perspectives, whether verbally or through visual separation. Finally, the Resolution stage can be identified by expressions of finality. This may occur, for example, through summarization or reiteration of selected previous statements, comment on the controversy as a whole, or a call for action.

Following the identification of the texts and labelling of the stages, the three discussion infographics were analyzed more closely using Martin and Rose's tools of Periodicity and Appraisal, the Richards-Engelhardt framework, and Economou's visual Appraisal approach.

6. Analysis and Discussion

The following chapters present the analysis of each discussion text individually. The three discussion texts generally deal with the question of whether GMOs are good or bad overall, yet they differ significantly in composition. Following a description of the infographic in question, including its layout and the presence and order of genre stages and phases, both discourse systems, Periodicity and Appraisal, will be addressed. For the purpose of this analysis, the discourse system labels of Periodicity and Appraisal are used as overarching terms to refer to the functions of these systems, information packaging and attitudinal expression, respectively, and not necessarily specifically to the linguistic realization of such functions. While this is already the default for visual Appraisal, which has developed out of linguistic discourse semantics, this is not the case for the Richards-Engelhardt framework.

Although these perspectives are treated as separate lenses through which the texts are analyzed, there may be some overlap, as the resources of each system are not only simultaneously present but work with each other to create meaning. This applies to the arbitrary separation of linguistic and visual resources as well. In addition to being a visual resource in itself, written language interacts with other graphic elements, which are themselves diverse, to create meaning. After an examination of all three discussion infographics, the main findings regarding the nature of these interactions will be summarized in section 6.4.

6.1. The good, the bad, and the ugly: a snapshot of the GMO debate

6.1.1. Identification of stages and phases

The first discussion infographic (Disc.1) is titled "The good, the bad, and the ugly: a snapshot of the GMO debate". It is a long vertical infographic that, on a standard screen, whether computer or mobile device, requires the reader to scroll in order to view the entire text (see 10.1). The stages of discussion are realized as

[Issue^Sides^Resolution] from top to bottom. The phases of Claim and Evidence are present for each side, although not displayed in the linear manner one would typically expect in a written text.

The Issue of Disc.1 spans from the top of the infographic to the three horizontal dotted lines situated above the two adjacent hand illustrations. All of the elements, both linguistic and visual, participate in establishing the field of interest. The title and subtitle announce the topic, while the introductory sentences explicitly identify the existence of a debate and invite the reader to read on, signaling there is more. This is especially evident in the use of the imperative: *Learn the backstory on a few of the most pressing issues of the controversy*. The information under the heading "What is a genetically modified organism (GMO)?" can also be considered part of the Issue, as it outlines basic facts about GMOs, including how they are made and examples of genetically modified crops. This background information serves as an orientation to the topic.

The first cohesive visual element of Disc.1, an illustration of a farm landscape situated above the written title, contributes to the function of the Issue as well. At first glance, one may interpret the illustration as a 'mere' depiction of agriculture, therefore signaling to the reader that the topic is related to farming in some way. While this is not false, the visual encoding principles at work within the individual graphic elements of the illustration convey more complex meaning. On closer inspection of the image, in Figure 10 below, one sees that the center path leading up to the barn acts as a boundary, grouping the elements on either side together, and that these sides are not identical. The illustration, therefore, not only represents that the topic is related to farming, but that there is some kind of difference in question. The significance of this difference will be discussed later in chapter 6.1.3.

Figure 10: Title image of Disc.1: asymmetry within the symmetry.

The thumbs-up and thumbs-down icons mark the beginning of the Sides stage, which makes up most of the infographic. A key characteristic of the discussion genre is the explicit consideration of more than one position (Martin & Rose 2008: 121). The adjacent icons with the accompanying headings (*the case for* and *the case against*) overtly introduce the two main sides presented in this discussion. Not only do the thumbs-up and thumbs-down icons symbolize "Case for" and "Case against" respectively, their corresponding alignment to the left and right establishes the visual and conceptual alignment that follows for the Claims and Evidence, as seen in Figure 11 below.

The Sides (for and against) are comprised of five Claims respectively, and each Claim includes at least one Evidence phase. Linguistically, the Claims are not presented explicitly, but the visual encoding principle of [grouping by alignment], used repeatedly in the Sides stage, works to fill in the linguistic gaps. The Claims are organized by subject matter, in which each topic is organized in a table of its own. By themselves, the headings are not a Claim for a particular side; their central positioning in combination with the thumb icons above and the Evidence in the table cells immediately below communicate the headings' meanings as Claims for either side of the discussion. It is only through alignment in the left column of the table that it becomes evident, for example, that the reported amount of herbicide use functions as Evidence for the Claim that GMOs result in less herbicide use, as illustrated in Figure 11. The tabular organization throughout the Sides stage works to assign the nominal attribute 'good' or 'bad' to the information presented.

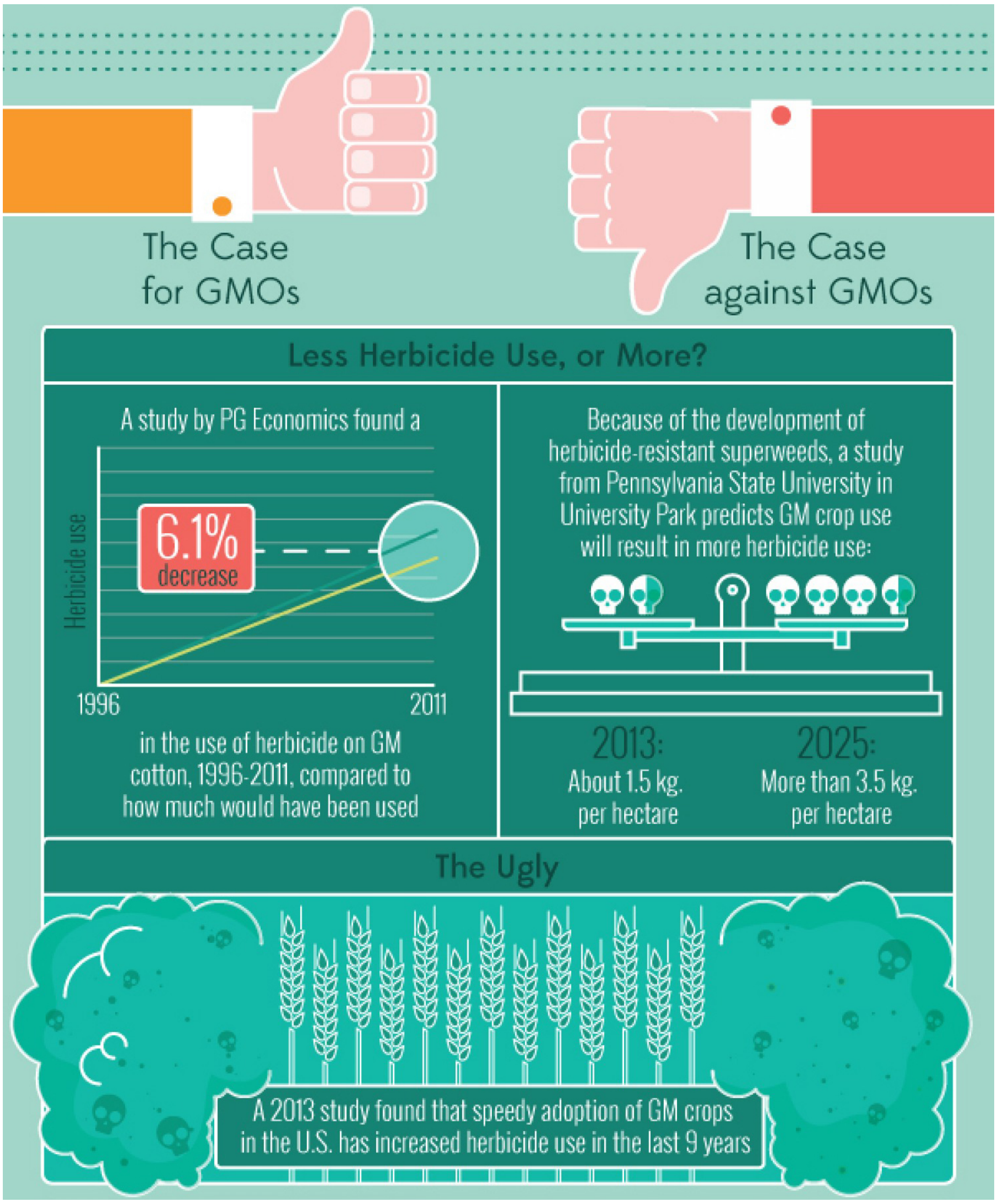

Figure 11: The beginning of the Sides stage of Disc.1. The combination of the thumbs-up and thumbs-down icons, verbal headings, and tabular organization of the Claims in Disc.1 helps the reader decipher which side the Evidence supports.

Each table in the Sides includes a centrally oriented section, titled "the ugly", which breaks with the preceding alignment. Despite the presence of a separate heading and nonconformity to the arrangement established at the beginning of the stage, the information presented in the "ugly" sections of each table are not considered to be a separate point of view. Rather these additional sections, both in labelling and positioning, contribute to the development of the author's overall stance, which will be further elaborated below.

The Resolution is the shortest stage, and visually distinct from all other phases. It consists of two complete sentences in which the author pronounces their judgement on the matter. It also contains a Recommendation phase; the imperative *stay on the lookout* charges readers with the task of keeping informed. Although the Resolution is realized primarily through written language, the presentation of text on a background markedly different than what has been used in the rest of the infographic separates the Resolution from the previous stages ([grouping by boundary]), giving it prominence.

6.1.2. Periodicity: information flow in Disc.1

The hierarchy of Periodicity in Disc.1 is expressed mainly through headings and subheadings. Due to the particular visual organization of the information, it is impractical to portray this hierarchy as a straightforward intended list, as typically done for written texts (see Martin & Rose 2007: 198). This format has been adapted and is shown in Figure 12, where the layers of macro- and hyperThemes are represented both through indentation and font size.

mT^{iii}	The good, the bad, and the ugly: a snapshot of the GMO debate	
hT	What is a genetically modified organism (GMO)?	
mT^{ii}	The case for GMOs	The case against GMOs
mT^{i}	Less herbicide use, or more?	
hT	The ugly	
mT^{i}	Spread of the superweed?	
hT	The ugly	
mT^{i}	The impact on yields	
hT	The ugly	
mT^{i}	The health debate	
hT	The ugly	
mT^{i}	The financial & social impacts	
hT	The ugly	
mT^{i}	Perhaps the greatest impediment [...] yet to be explored.	

Figure 12: Theme hierarchy for Disc.1. The blue, red, and green on the left represent the genre stages (Issue, Sides, and Resolution, respectively). Position of macroThemes (mT) and hyper-Themes (hT) in the hierarchy is indicated by the use of superscripts (for mT), font size, and indentation.

The title and subtitle of the infographic serve as the macroTheme of the highest order (mT^{iii}); they establish the expectations not only for the Issue stage, but for the entire text as well. Apart from announcing the topic of the infographic (GMOs), the title and subtitle express that it is something contested (*debate*), and that there is more than one perspective to be addressed (predicting the Sides stage). Visually, these are set apart through [grouping by boundary]; with the lighter background, they stand in contrast to the rest of the infographic, attracting attention and signaling their predictive function. The farm landscape, as described above in 6.1.1, also contributes to this meaning by triggering associations for the reader, which are given more concrete form in combination with the title.

The table heading *What is a genetically modified organism?* functions as a hyperTheme, establishing reader expectations for the rest of the table. The question behaves like a topic sentence of a paragraph, in which various aspects of GMOs are briefly described. While the information itself is not presented in paragraph form, the tabular representation, an application of the visual encoding principle [grouping by alignment], shows that all of the information belongs to the same category.

The Sides stage is introduced by two verbal macroThemes of equivalent rank: *The Case for GMOs* and *The Case against* GMOs. Visually, the beginning of this stage is signaled through the thumbs-up and thumbs-down illustration, whose evaluative meaning (see 6.1.3 below) also works to frame the rest of section. The adjacent positioning of these macroThemes^{ii} in Figure 12 mirrors their placement in the infographic itself because of how the rest of the text is organized. The reader is met with both sides of the issue simultaneously, and the fulfillment of the expectations set up by these macroThemes^{ii} does not occur consecutively. In other words, although the reader, following the left to right reading conventions in English, looks at one macroTheme^{ii} before the other, the layers of News for each of these macroThemes^{ii} are fulfilled in waves of lower order macroThemes^{i} (the table headings; for example, *less herbicide use or more?*) and hyperThemes (*the ugly*). This oscillation between pieces of information that alternately fulfill the expectations created by the adjacent Sides' headings leads up to the Resolution, which begins a new wave.

The headings of each table in the Sides stage are not treated as hyperThemes, as with the table ('paragraph') in the Issue, because of the more complex structure of these tables. There are several layers of information present here; not only does the information pertain to the immediate topic heading, but it refers to one side or the other. *The Ugly*, as a subheading within each table in the Sides, functions as a hyperTheme in that it creates expectations for a specific type of information and is presented in a visually distinct manner.

As a significantly shorter stage, there is not much room in the Resolution for creating expectations above the clause level. Despite this, a macroTheme role is clearly fulfilled visually. The use of [grouping by boundary] through a distinct background color indicates something new is happening. Within the stage itself, the first sentence of the Resolution acts as a macroTheme[i] on par with the topic headings in the Sides (Figure 12); in expanding upon the Claims against GMOs with *[p]erhaps the greatest impediment is […]* the author sets up the reader for the recommended action. As a whole, the Resolution also acts as the highest order hyperNew both visually and verbally (see Figure 5), in which the accumulated information from the Sides is pulled together to form a conclusion.

6.1.3. Appraisal: negotiating attitudes in Disc.1

Appraisal resources work together to convey the author's overall stance on the controversy, which in Disc.1 seems to be an attitude of caution and skepticism towards GMOs. The author primarily uses APPRECIATION to present their understanding of GMOs and how they relate to various aspects of human life. As the subject matter at hand deals with a scientific process (genetic engineering) and the products thereof (GMOs), it is not surprising that APPRECIATION resources dominate the expression of attitude. However, punctuated instances of AFFECT and JUDGEMENT are key to understanding the nuances of the discussion.

The first stage of the discussion works to generate the overall mood. In this way, the Appraisal resources work together with Periodicity to create reader expectation. This begins directly with the title, in which one instance of positive APPRECIATION (*good*) is followed by two successive instances of negative APPRECIATION (*bad, ugly*), all of which assess GMO quality in some way (see Martin & White 2005: 56). The repetition of negative APPRECIATION results in an asymmetrical manifestation of attitude. Graduation enhances this asymmetry. *Ugly*, as an intensification of *bad*, results in a more forceful expression, indicating to the reader that although there is more than one side to consider, the negative aspects prevail.

Notable are the instances of JUDGEMENT in the Issue which seem to echo the biased sentiment of the title, seen in the examples (5), (6), and (7) displayed below.

(5) The debate continues over whether genetically modified organisms are out to save the world or destroy it.

(6) When were they introduced to our food supply?

(7) 6 companies control almost 70% of the world pesticide market, and almost the entire GM seed market […]

Although we are dealing with things and not the behavior of people, the first sentence of the introductory text, (5), seems to express JUDGEMENT about GMOs. JUDGEMENT is ordinarily reserved for evaluating the behavior of those who can be held responsible for their actions; this poses the question: can GMOs, as non-sentient organisms, carry out an action that is subject to social norms? Perhaps not; however, the expression *out to* ascribes intention to GMOs, making them susceptible to the author's sanction, whether praise (*save*) or condemnation (*destroy*).

Further reading of the Issue stage reveals an imbalance in the expression of JUDGEMENT that, as with APPRECIATION in the title, leans negatively. The question posed in (6) seems neutral at first glance, but upon closer inspection contains invoked JUDGEMENT of an unidentified actor. This is accomplished through non-attitudinal lexis, specifically through the juxtaposition of *they* and *our food supply*. The contrast between the third person pronoun and second person possessive pronoun creates distance between GMOs ("they") and the food supply, implying that GMOs are not supposed to be a part of the food supply. As a result, the act of introducing them is judged negatively.

Finally, the negative JUDGEMENT expressed in (7) is likewise implicit and dependent on contextual clues for interpretation. Again, two aspects are juxtaposed to demonstrate a disproportionate relationship. The number of companies is considerably small in comparison to the share of the markets they control, an imbalance created by the companies themselves. These asymmetrical instantiations of JUDGEMENT and APPRECIATION in the Issue stage establish the prosodic rhythm for the rest of the text.

The role of the title image in conveying attitudinal value cannot be ignored, although this expression may not be as salient as in the title itself. The farm landscape (Figure 10, section 6.1.1.) evokes a mix of JUDGEMENT and APPRECIATION, two attitude types that are even more difficult to distinguish visually than verbally (Economou 2009: 121, 136). The sun and storm clouds to the left and right of the barn, respectively, evoke attitudinal values dependent on shared cultural knowledge. Sunny weather carries positive connotations; stormy weather carries negative connotations. As depictions of natural phenomena (weather), they can therefore be interpreted as positive and negative APPRECIATION, respectively. Through these elements, the attitudes expressed by the rest of the illustration can be understood. The symbolic fields on either side of the figure are sprinkled with green dots, depicting crops; smaller ones on the left and larger ones on the right, an instantiation of force [quantification: mass]. While these dots do not encode attitudinal meaning on their own, the scaling of their symbolic ideational meaning, together with the attitudinal values of the sun and storm cloud, invite an evaluative reading of the depicted fields that corresponds to that of the weather icons. Agriculture is a human practice and despite the absence of a human participant in the image, invoked values of JUDGEMENT for the farmers who have planted these fields are present in addition to the invoked APPRECIATION.

The attitudinal expectations generated by the infographics' title are fulfilled in the Sides. The APPRECIATION triplet is present again: positive APPRECIATION (*the case for*, thumbs-up) and negative APPRECIATION (*the case against*, thumbs-down) introduce the stage; and these are followed by graduated negative APPRECIATION (*the ugly*), which reoccurs with each Claim. These headings possess predictive power as well, working together with Periodicity (see section 6.1.2.) to create expectations regarding the attitudinal meanings to follow.

APPRECIATION values manage the overall attitude in the Sides, but as in the Issue, this veil of APPRECIATION is accented by additional and overlapping Appraisal resources. Although not always explicit, these expressions of attitude work together to contribute to the prosodic pattern mentioned above. The most significant and prevalent resources used, both verbal and visual, will be discussed below.

One repeated instance of overlapping APPRECIATION and AFFECT is the word *superweed*. So-called superweeds are unwanted plants that have become herbicide-resistant, and therefore almost impossible to control, often mistakenly thought to have directly emerged in the wake of genetically modified organisms (Twyman et al. 2009: 610). Although *super* is a positively connotated adjective on its own, its combination with the negatively connotated *weed* has the opposite effect. Not only does it bestow *weed* with more strength [Graduation: force: intensification], but through this instance of Graduation it evokes negative AFFECT in addition to the inscribed negative APPRECIATION; the weed is something unwanted [-APPRECIATION: reaction: quality], but also something difficult to control [AFFECT: insecurity].

Additionally, there are instances of APPRECIATION-AFFECT overlap which, as Evidence for the "case for GMOs", provide a hint to the reader that the argumentation is moving in the opposite direction. Example (8) below not only expresses negative APPRECIATION [composition: balance] regarding the lack of predictability in the development of herbicide resistance, but evokes a sense of [AFFECT: insecurity] through the use of *no matter what*.

(8) Herbicide resistance develops no matter what

(9) A comprehensive meta-analysis conducted at Stanford University found no strong evidence that organic food is more nutritious or less likely to carry health risks compared to conventional foods

In (9), the author expresses positive APPRECIATION [composition: balance] towards the study itself. However, the Graduation resources used to hedge the statement (*no strong*, *less likely*) in combination with the mention of health risks, potentially invokes negative AFFECT. In other words, although this statement is in support of GMOs, it may trigger any preoccupations the reader has with health issues. These two examples do not directly correlate with existence or non-existence of GMOs, weakening the case for GMOs.

Resources of visual Appraisal convey predominantly AFFECT values in the Sides. This is done in various ways. Explicitly, AFFECT is inscribed in the facial expression of the illustrated man, depicted in Figure 13. His unhappy and almost sickly expression suggests an attitude not expressed verbally. The listed symptoms to the right are all instances of negative APPRECIATION, as they concern natural processes. The strategic placement of a personified figure next to the text may cause the reader to viscerally ascribe AFFECT to the verbal cues as well.

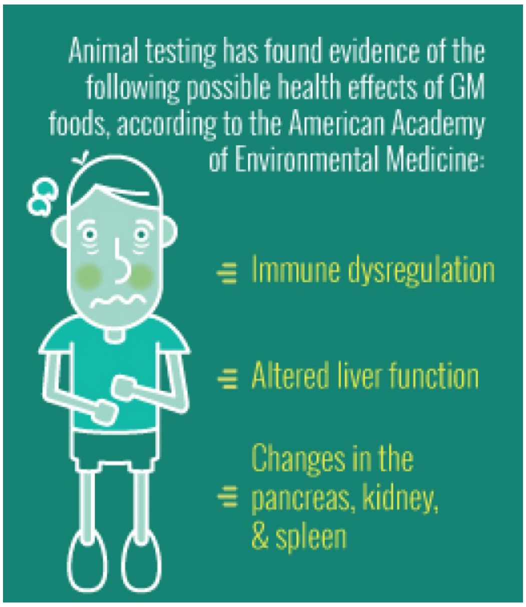

Figure 13: Interaction of visual AFFECT and verbal APPRECIATION.

Additionally, AFFECT is provoked through the use of the human skull icon in combination with information about herbicide and pesticide use, shown in Figure 14. Herbicides and pesticides do not target humans and therefore would not result in human death (theoretically, assuming correct use). However, the skull as a symbol of death and danger has deep historical roots; it has been used in the labeling of poisonous substances for over 150 years (Griffenhagen & Bogard 1999: 92-93). While *herbicide use* and similar phrasing appraises primarily through APPRECIATION, the accompanying skull symbols invoke negative AFFECT, conveying a sense of insecurity.

A third salient feature of visual Appraisal resources in Disc.1 is the attitude invited by Graduation resources present in the Isotype charts. In these representations, in which a symbol or picture is repeated to express quantity, the visual encoding principles of [picturing] and [repeating] work together. Attitudinally, this can have a significant effect. According to the system of visual Graduation (section 5.2.6.2.), the Isotype charts in Disc.1 may express force through either [quantification: number] or [repetition], or both. For example, the twelve paper icons in Figure 15 correspond to the text describing the same number of studies. As a result of this reoccurrence, a heightened sense of importance ([+APPRECIATION: valuation]) is conveyed. A single icon would not have this effect; it is only through the depiction of many ([quantification: number]) that this attitudinal reading is invited, conveying a sense of visual legitimacy. In contrast, the skull icon utilized in the quantitative representation in Figure 14a conveys negative AFFECT on its own. Through [repetition], this value is magnified.

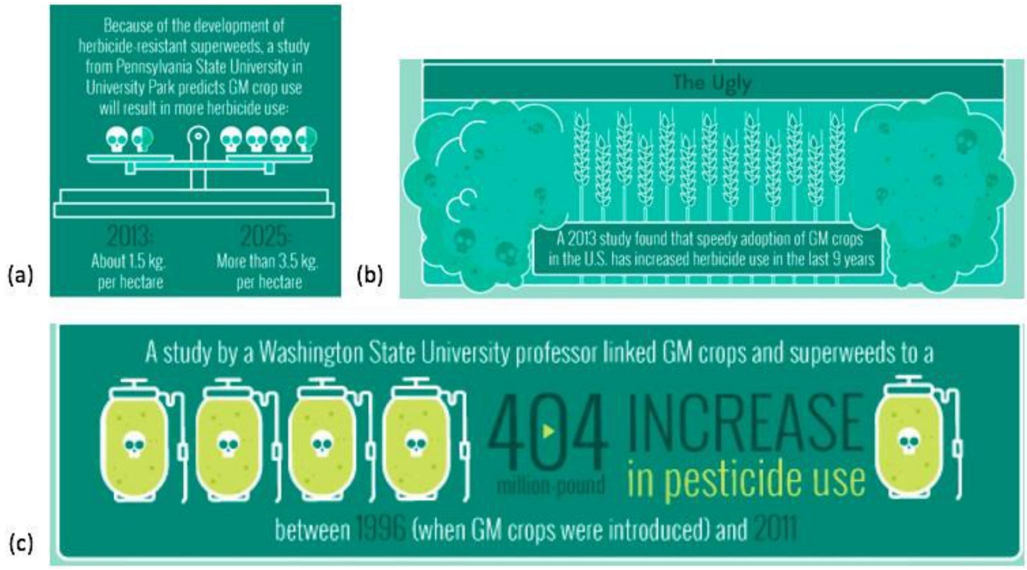

Figure 14: The use of the skull icon in combination with herbicide or pesticide use, in order of occurrence in the infographic.

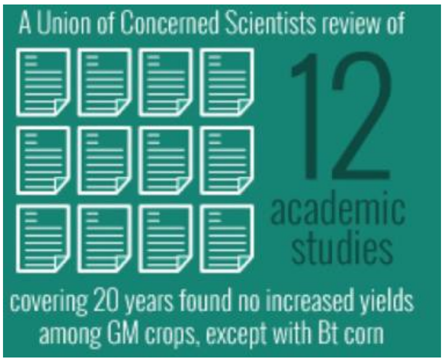

Figure 15: The combination of the principles of [picturing] and [repeating] in the Isotype chart result in invoked positive APPRECIATION [valuation].

6.2. Genetically modified foods: good or bad?

6.2.1. Identification of stages and phases

The organization of information in the second infographic, “Genetically Modified Foods: Good or Bad?” (Disc.2), contrasts with the conventional organization of discussion genres. Much like Disc.1, this infographic is vertically aligned, but shorter in length and, depending on the screen, would not require scrolling to read (see 10.2). The three discussion stages occur in an unconventional order, namely [Issue^Resolution^Sides], which has consequences for how the infographic is read and understood.

The Issue of Disc.2 encompasses approximately the first quarter of the infographic and consists of only the title and subtitle, along with the accompanying graphic elements (place setting and banner). The topic of discussion is established simply by mentioning the object of discussion (GMOs) and presenting two possible points of view on the topic: GMOs are good, or GMOs are bad. The title illustration may serve to trigger associations with food and nutrition; otherwise, no other background information is provided.

The Resolution, which immediately follows the Issue, is the shortest stage. It is comprised of two short statements. The first, *educate yourself*, functions as a Recommendation, encouraging the reader to become informed on the topic. The second statement, *everyone needs to weigh in on this serious matter*, communicates the author's judgement of the issue as one that is not to be taken lightly, although it is unclear at this point to which side (good or bad) the author leans.

A red dotted line signals the begin on the final stage, the Sides. The two perspectives are presented consecutively, separated by a gray dotted line, the encoding principle of [grouping by boundary] in effect. Each side is designated by a heading that introduces the Claims as support for the 'good' or 'bad' side. Information for each side is grouped through a combination of [linking] and [grouping], though not in the same manner. The inconsistent layout of the Sides has consequences for the text's information flow and attitudinal prosody.

6.2.2. Periodicity: information flow in Disc.2

The layering of information in Disc.2 seems to present a relatively simple hierarchy of information. However, the text does not develop in a straightforward manner. Expectations that are created through the text's macro- and hyperThemes are not always fulfilled as anticipated, leading to potential ambiguity.

The title as macroTheme^{iii} has the most predictive power regarding the text's development, as shown in Figure 16. This coincides with its role as the Issue of the discussion, in which it introduces the controversy. A second wave of expectation is created by the Resolution, which also functions as a macroTheme^{ii}. Consequently, the reader not only expects both good and bad aspects of genetically modified foods to be addressed, but to learn valuable and useful information. This is reinforced visually by the red dotted line, which, through [grouping by boundary], signals that this information will follow.

mT^{iii}	Genetically modified foods: good or bad?
mT^{ii}	Educate yourself - everyone needs to weigh in on this serious matter
mT^{i}	Why its [sic] good
hT	Pest resistance
hT	Herbicide tolerance
hT	Disease resistance
hT	Nutrition
mT^{i}	The bad side
hT	Of course if done right...

Figure 16: Layers of macro- and hyperThemes in Disc.2.

The identification of verbal elements of Periodicity in the Sides stage is strongly influenced by their visual organization. The first viewpoint is introduced by the heading *why its [sic] good*, which has been identified here as a macroTheme^{i}. Although principles of [grouping by color] and [nesting] work to establish a paragraph-like structure between the heading and the remaining elements between the red and gray dotted lines, the title has greater predictive scope within the stage itself. The Claims, as concise bullet points nested directly below the heading, shown below in Figure 17 seem to anticipate more detail; they signal the direction the phase is taking (Martin & Rose 2007: 194). They are labeled as hyperThemes for this reason. The brief example to the right of this list, a hyperNew, fulfills this expectation by providing an example of how pest resistance and the other traits are ‘good’.

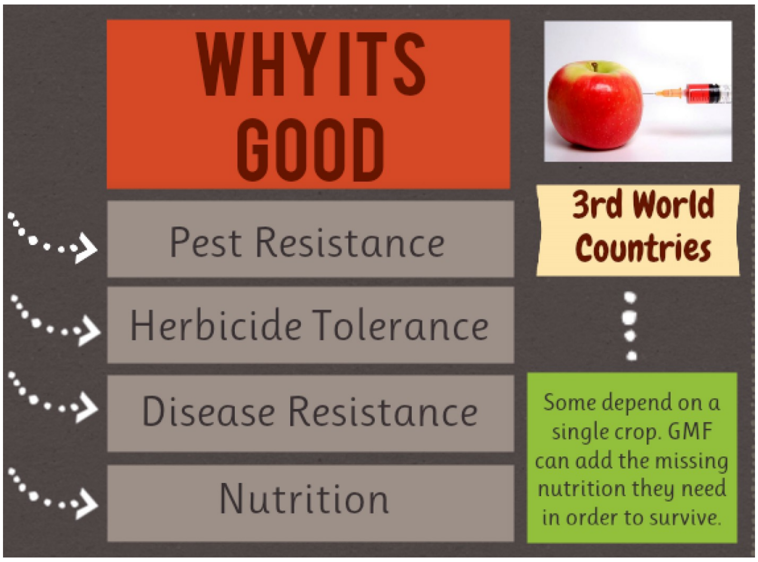

Figure 17: The beginning of the Sides stage in Disc.2. The listed elements on the left act as Claims; the two text boxes connected with the vertical dotted line at the right supports these claims.

Information in the second half of the Sides is visually (more or less) similar, but the lack of consistency results in ambiguity. The same visual encoding principles are employed, yet not in the same way (different colors, pointing finger instead of arrows, dotted line linking the boxes), which instantly creates a hint of discord. Nonetheless, the expectation is the same: the title as a macroTheme[i] will keep the stage moving by predicting the type of information that will be considered; one or more hyperThemes will introduce the Claims and Evidence. However, the two text boxes below the title present more detailed information that seems to function more as Evidence without preceding Claims. The reader still may expect additional related information, as above, but in contrast to the first part of the Sides, there is no further development of this information. Instead, a new hyper-Theme (*Of course if done right…*) is introduced, which seemingly contradicts the macroTheme of the section.

Disc.2 does not seem to form a regular pattern of information. This lack of rhythm makes it more difficult for the reader to follow the argumentation and meaningfully extract the pros and cons of each side (see Martin & Rose 2007: 189). Moreover, the attitudinal fluctuation of both the verbal and visual elements may potentially create confusion.

6.2.3. Appraisal: negotiating attitudes in Disc.2

The use of Appraisal resources in Disc.2 generates an overall mood of distrust towards actors commercially involved with GMOs, while simultaneously appreciating the advantages of GMOs. The first two stages, the Issue and Resolution, create the attitudinal expectations for the rest of the text. First the title, which is in part formulated as a question, presents a choice between two possible conclusions. Either GMOs are good [+APPRECIATION: reaction: quality], or they are bad [-APPRECIATION: reaction: quality].

The Resolution contains three instances of positive Appraisal, but these cannot be automatically understood as an expression of a favorable attitude on the part of the author towards GMOs. The phrase *serious matter* conveys [+APPRECIATION: valuation], revealing the author's opinion that the topic is worth sincere consideration. Indeed, it is considered a moral responsibility to deal with the issue. This sentiment is expressed through *everyone needs to weigh in*, an expression of positive JUDGEMENT [social sanction: propriety]. Additionally, with the imperative *educate yourself*, the author adds a layer of [social esteem], signifying the respect that the reader would earn if they follow through. GMOs are the subject of debate, but this use of Appraisal resources does not explicitly denote any partiality towards GMOs themselves on behalf of the author.

Expressions of positive APPRECIATION dominate the Sides, but their interactions with instances of AFFECT and JUDGEMENT are responsible for the overall sentiment. The first point of view, the 'good' side of GMOs, begins with a reiteration of the positive APPRECIATION expressed in the title. This expression of attitude has an important textual function; it is an example of interaction between Appraisal and Periodicity resources, connecting back to the title and indicating what is to come. The four Claims underneath the heading are also instances of positive APPRECIATION attributed to GMOs. Unlike the heading, however, these are all implied and rely on context for interpretation. The first piece of contextual knowledge needed is the information given explicitly in the heading above, which communicates to the reader that the items below establish why GMOs are good. Additionally, one needs to be aware of how each of the listed attributes affects society, such as the challenges that face the agricultural industry (pests, weeds, disease) and the importance of nutrition.

The Evidence to the right of the list of Claims adds a layer of Appraisal to this section that contributes to understanding the author's earnestness in the Resolution above. On the surface, the statement is yet again an expression of positive APPRECIATION: the positive characteristics of GMOs, listed to the left, ultimately provide nutritional value. At the same time, negative AFFECT is invoked though the notion of survival. The phrase *in order to* constructs a meaning of need and dependency, suggesting a state of [insecurity]. The invoked negative AFFECT has the potential to not only create reader sympathy for third world communities, but to convince the reader that GMOs are indeed a serious matter.

The opposing side, "the bad side", shown below in Figure 18, presents a less cohesive picture. The reiteration of *bad* in the heading serves the same organizational purpose as above; however, the evaluations made below the heading turn the evaluation away from GMOs themselves. The first Evidence phase only indirectly appraises GMOs. The negative APPRECIATION [valuation] is directed at potential phenomena (gene transfer) that additionally has potential negative effects. The second Evidence phase does not deal with GMOs at all. Rather, the author confidently, through the use of *will*, conveys negative JUDGEMENT [social sanction: propriety] towards private companies, which the author feels act unethically.

Moving to the right, the reader is confronted with an apparent contradiction. Although this section is clearly a part of the 'bad' section, it lists several positive qualities of GMOs. The prefacing heading (*of course if done right…*) links the information to the Evidence phases on the left and through the conjunction *if* creates a sense of doubt, evoking negative AFFECT. Additionally, the phrase *done right* implies there is a correct way to act, an invoked sense of JUDGEMENT of unnamed actors. As a result, the positive APPRECIATION expressed in the list below is weakened.

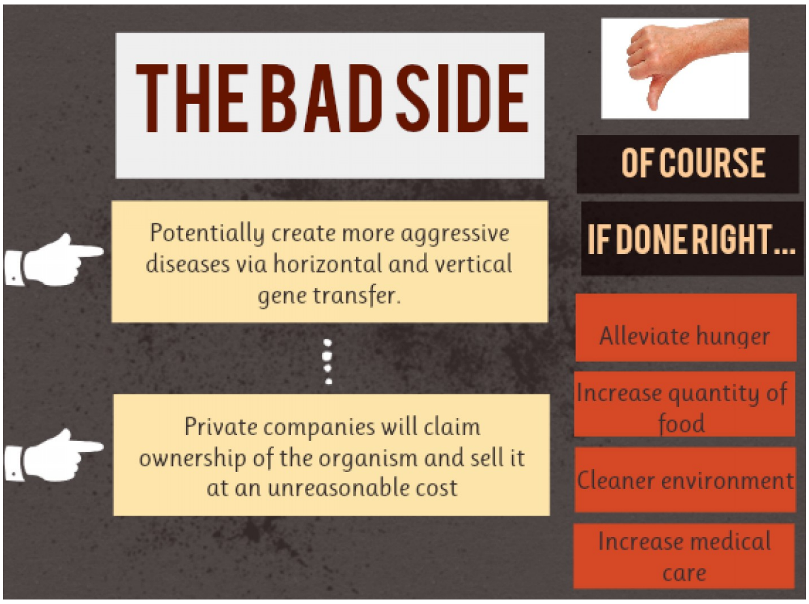

Figure 18: Seemingly contradictory realizations of JUDGEMENT and APPRECIATION in Disc.2.

The two photos in the Sides stage contribute to the overall negative attitude towards GMOs. First, the syringe and apple are two ideational tokens that do not normally belong together, possibly triggering negative AFFECT in the reader. The action portrayed through the syringe as a vector can be seen as something unnatural, and therefore an instance of negative APPRECIATION. Grouped with the positive arguments for GMOs, this photo seems to weaken the Claims in support of this side. The second photo, a thumbs-down gesture, expresses negative attitude more directly, a combination of negative APPRECIATION and negative JUDGEMENT, corresponding to the Evidence provided in that section.

The Sides as a whole give closure to the Resolution. The characterization of the matter as serious simultaneously expresses the author's disheartened attitude towards issues surrounding GMOs. The expression of positive Appraisal is muted by the juxtaposition with negative expressions of attitude, fueled predominantly by a lack of trust in people and corporations.

6.3. What do you know about GMOs?

6.3.1. Identification of stages and phases

While the titles of Disc.1 and Disc.2 promptly signal that opposing positions on the topic will be considered, the last discussion infographic has a less obvious discussion title. “What do you know about GMOs?” (Disc.3) engages the reader with a seemingly open-ended question without referring to advantages or disadvantages of GMOs. However, positions for and against GMOs are explicitly laid out the further one reads. In this horizontally oriented infographic (see 10.3), the stages and phases are presented in the conventional order, [Issue^Sides^Resolution], granted one reads left to right and top to bottom, moving from the top left corner to the bottom right corner.

The Issue of Disc.3 occupies the top half on the infographic and is discernable from the other stages both verbally and visually. Verbally, the Issue functions to provide the reader with background information about GMOs. A definition is provided, and three questions organize content questions. While this stage is not devoid of attitude, there is no explicit designation of any point of view. Visually, the [grouping] encoding type has a dominant role in the composition of the Issue stage. The main principle at work here is [grouping by boundary]. The light grey background creates a zone in which various facets of the subject matter are presented. While the title and definition of GMOs are on a darker background, the light grey silhouette of the grain links the two areas together. Likewise, although the light grey background extends to the lower half of the infographic, other visual conventions help define the Sides and Resolution stages.

Identifying the beginning of the Sides stage is straightforward; however, differentiating between Sides and Resolution, or rather recognizing the Resolution stage as such, involves careful reading. The Sides, consisting of a ‘good’ and ‘bad’ perspective, are introduced consecutively, complete with Claim and Evidence phases. First, the ‘good’ side is presented with assertions for why GMOs are advantageous (Claims), each followed by an explanation for this assertion (Evidence). Following this, the ‘bad’ side is introduced.

The Sides stage is organized through various principles of grouping. Individual Claims, the corresponding Evidence, and associated symbols are brought together in groups of separate dark grey rectangles, utilizing the principle of [grouping by boundary]. Association with a specific side of the discussion is communicated through a combination of [grouping by proximity] and [nesting], through which the rectangles are aligned near each other but under a respective heading, creating a hierarchy consisting of the heading (*the good* or *the bad*) and the information contained in the boxes. Furthermore, color in the heading, key words and symbols is used to unite the Claims and Evidence with their respective viewpoint ([grouping by color]).

The last stage, the Resolution, occupies the lower right corner of the infographic. Visually, it is not as distinct from the Sides as it is from the Issue because the same principles of [grouping by boundary], [color], and [proximity] are used in both the Sides and Resolution. However, there are fewer segments and a lack of pictorial representations which, in addition to the use of a distinct color, create a slight distinction. These slight differences, along with the attitudinal resources, discussed in 6.3.3, give form to the author’s opinion on the matter.

6.3.2. Periodicity: information flow in Disc.3

Headings and subheadings, along with their contrast in color and font size, create the hierarchy of Periodicity in Disc.3, displayed in Figure 19. Once more, the title serves as the highest order macroTheme. However, the question form of the title offers unique potential for the creation of expectations. The question prompts the reader to recall any previous knowledge on the topic or may trigger particular associations, which consequently provides room for more individual expectations regarding what information will follow. Regardless of individual expectations, it is the author who dictates that the information included merits the reader’s attention.

Periodicity in the rest of the infographic is neatly organized into categories of information that aim toward fulfilling the author’s goal. The heading of each category functions as a macroTheme of equivalent degree (Figure 19), spanning across genre stages.

mT^{ii}	What do you know about GMOs?
mT^{i}	Genetically engineered...to do what?
hT	Commercially
hT	In research
mT^{i}	Who owns it?
hT	Biotech patent ownership
mT^{i}	Who grows it?
hT	% world GMO crop area by country
mT^{i}	The good
hT	Reduction in insecticide use
hT	Can produce higher yields
hT	Benefits for farmers
hT	Can provide defence against aggressive disease
hT	May help fix big world problems
mT^{i}	The bad
hT	Concerns about health
hT	Concern with IP ownership
hT	Superbugs and superweeds
hT	Lack of transparency
hT	May cause big world problems
mT^{i}	The ugly
hT	The conversation is confusing & sensational
hT	Major GMO producers are hard to trust

Figure 19: Periodicity in Disc.3.

Three macroThemes, apart from the title itself, serve to organize the information in the Issue, each likewise formulated as a question. Visually, [grouping by color] is a prominent encoding principle that supports this interpretation. The headings of each section of the Issue are in green, while subheadings are in yellow and body text in white, indicating a hierarchy of information. Although one may think of these headings as hyperThemes, each introducing a separate 'paragraph' (one on what they are engineered to do, a second about ownership, and a third about cultivation), a macroTheme interpretation is favored here due to the relatively complex composition of the first section of the Issue, displayed in Figure 20. Each of the two subordinate headings ("Commercially" and "In Research") anticipates a particular type of information. Additionally, distinct encoding principles work to organize this information ([proportioning] and [grouping by color] on the left, [nesting] and [grouping by alignment] on the right), creating further distinction between the two subsections. As a result, the heading in green functions as a macroTheme, predicting the type of information in that section, whereas the subheadings are analogous to topic sentences. The additional aspects of the Issue function similarly, in which the larger green heading predicts more general information and the smaller yellow print beneath introduces the graphics.

Figure 20: Visual layout of two macroThemes and their subordinate hyperThemes in the Issue of Disc.3.

The rest of the infographic follows this rhythm. Each section has a clear heading that anticipates the kind of information to follow, and subheadings for specific aspects of the topic. The consistency of [grouping], as described in 6.3.1, also contributes to these consistent waves of information.

6.3.3. Appraisal: negotiating attitudes in Disc.3

The Appraisal resources utilized in Disc.3 ultimately express a sense of reservation, but, overall, conveys more optimism than in the other two infographics. Yet again, and unsurprisingly, APPRECIATION resources dominate the discussion.

In contrast to Disc.1 and Disc.2, the Issue stage in Disc.1 begins with an instance of JUDGEMENT. However, this JUDGEMENT is not directed towards individuals or institutions involved in the GMO industry, but rather the reader him/herself. The title, “What do you know about GMOs?”, calls into question the reader’s intellectual or experiential capacity regarding the topic (cf. Martin & White 2005: 53), simultaneously expressing the author’s opinion that the subsequent information is valuable.

Attitude values conveyed in the rest of the Issue essentially constitute positive APPRECIATION, establishing a relatively optimistic outlook on GMOs. The author uses phrases such as *desirable trait*, *herbicide-resistant*, *enhanced nutritional content*, *help with…deficiency*, and *promising genetic modifications*. If readers have already formed negative associations with GMOs, they may interpret phrases such as *insect-resistant* and *herbicide-tolerant* as negative. However, these phrases are being used in relation to commercial use, where insects and weeds are considered to be pests, and therefore, such traits in crops are considered beneficial. The one instance of invoked AFFECT in the Issue also works to support a case for GMOs. With the statement *9 of every 10 farmers planting GMOs are resource-poor and living in developing countries*, the author potentially creates sympathy in the reader for the farmers who rely on GMO crops for their livelihood.

The pattern of Appraisal resources in the Sides do the most to shape the author’s stance. The attitudes expressed in the Sides’ headings (positive and negative APPRECIATION, respectively) frame the overall attitude for the following phases, but it is the mix of different attitudes in combination with resources of Engagement and Graduation that make the author’s stance clear.

The Claims in support of GMOs overwhelmingly convey APPRECIATION values, expressing why the production and cultivation of GMOs are worthwhile (cf. Martin & White 2005: 56). This is reinforced by attitudinal overlap with both negative and positive AFFECT, as seen in Figure 21 below. The combination of *defence* with *aggressive disease*, a phrase in which Graduation resources are used to create intensity, conveys a sense of security against potential danger. This is mirrored in the accompanying Evidence phase, in which the author describes a *crisis* in the papaya industry, whose future was subsequently *saved* by a GMO version of the crop. Furthermore, in a different Evidence phase, the author quotes directly from the Food and Agriculture Organization of the UN, a respected international body. This instance of heteroglossia, in which the quote is not introduced through a transitional phrase, can be interpreted as the author's expression of solidarity and attitudinal agreement with the sentiment expressed in the quote (cf. Martin & White 2005: 96). Overall, this part of the stage seems to reinforce a sense confidence in GMOs, as it not only reflects the APPRECIATION expressed in the Issue, but also infuses it with a hint of emotion through AFFECT.

Figure 21: Attitudinal overlap: positive APPRECIATION, positive AFFECT, and negative AFFECT.

An examination of the Appraisal resources utilized in the alternate side of the discussion, "the bad", indicates the author's nuanced stance on the issue. As with the first half of the stage, the negative APPRECIATION expressed in the heading establishes an attitudinal expectation for the rest of the section. Yet, there is more variety in the type of resources used. The first three Claims, situated below in Figure 22, convey negative AFFECT, communicating meanings of [disinclination] or [insecurity] (see Martin & Rose 2005: 51) through the recurrent use of *concern* and the mention of *superbugs* and *superweeds* (see also section 6.1.3).

Additionally, in the Evidence phases of each of these Claims, the author seems to create distance between him/herself and the opinions expressed. The mention of allergic reactions (Figure 22a), which can have serious consequences, evokes negative AFFECT, reinforcing the AFFECT in the Claim. At the same time, the author uses modality (*could result*) to express probability, reducing the strength of the Evidence. Such an instance of downscaled Graduation also occurs in Figure 22c. The second Evidence stage (Figure 22b) repeats the concern of the Claim, along with negative JUDGEMENT of corporations, but this concern is prefaced with *GMO opponents*. This is different than the use of the unintroduced quote in the first side; by explicitly prefacing the information with the source of concern, the author does not adopt the concern as his/her own.

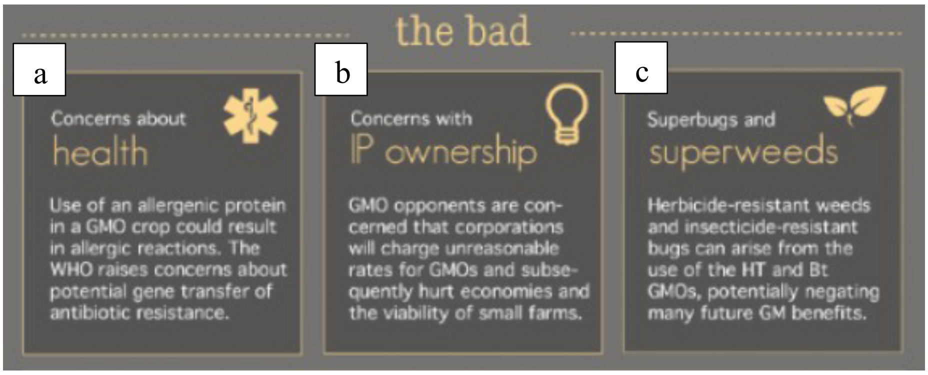

Figure 22: The first three Claims and Evidence phases of "the bad" in Disc.3 show attitudinal overlap.

The short Resolution stage, shown in Figure 23, synthesizes the attitudes expressed throughout the Issue and Sides, consolidating the author's stance as one positioned neither clearly for nor clearly against GMOs themselves, but as one against inflexible positions on the topic. As predicted by the heading, an expression of graduated negative APPRECIATION, the Resolution expresses negative attitude. The top half of the stage articulates negative APPRECIATION as well. However, this negative appraisal is not directed towards GMOs, but the debate itself. The author's description of the issue as *confusing* and *sensational* is bolstered by the use of a direct quote from the International Food Policy Research Institute. This instance of heteroglossic Engagement not only echoes the author's opinion (*differentiating fact from fiction is not easy*), but as a direct quote without a reporting verb, reduces the distance between the author and the Institute. The bottom half of the stage is dominated by negative JUDGEMENT towards companies that produce GMOs. They are characterized as being *hard to trust* because they have *violated the public trust*. Resources of Engagement are used here as well. The author explicitly criticizes these companies, but, in explicitly prefacing *companies producing GMOs will prioritize profits over human welfare and the* *environment* with *GMOs opponents fear that*, simultaneously suggests that he/she is not necessarily a staunch opponent of GMOs, something that has been alluded to through the widespread use of positive APPRECIATION throughout the Issue itself.

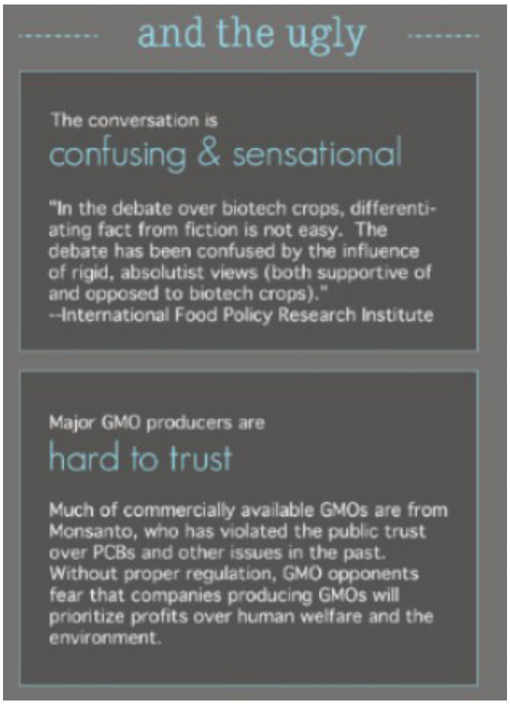

Figure 23: The Resolution stage of Disc.3.

Until now, visual Appraisal resources in Disc.3 have not been acknowledged. This is because the interpersonal meaning expressed in each stage of discussion is expressed primarily through verbal means. However, this does not mean that attitudinal values cannot be interpreted from the visuals. The symbols used in the Issue and the Sides do not have explicit affective value; they are predominantly standard symbols that one might find in word processing or presentation software. The repeated use of such symbols creates a sense of impartiality not present in the others. Consequently, the author's use of positive or negative Appraisal does not appear as polarized as in the other two infographics.

6.4. Summary and discussion

As previously mentioned, it is worth noting that there were only three identifiable instances of discussion among the 17 infographics classified as performing argumentation. Although generalized statements cannot be made regarding the nature of argumentation about GMOs in infographics based on this data, it is compelling that less than a quarter of these argumentation texts explicitly deal with evidence both in support of and against GMOs. It is reasonable to assume that individuals who read any given infographic online, either through an active search or random encounter, are not automatically presented with a diverse range of perspectives.

The combination of frameworks proved valuable for the analysis of these multimodal discussion texts. A blend of approaches is not unusual when investigating multimodal texts, especially non-conventional texts (cf. Cmeciu, Manolache & Bardan 2016: 55-56; Martin & Rose 2007: 324-330). The tools of discourse semantics provide an appropriate point of departure for the analysis of text, as they outline patterns of meaning instead of focusing on structural features. While this approach to discourse was developed from a linguistic perspective, the concept of metafunction itself is not inextricably linked to language and is therefore applicable to other semiotic resources

The framework from Engelhardt and Richards (2018) has emerged from research in information design; however, it is compatible with the notions of Periodicity and textual meaning. First, the authors highlight the function of graphic components instead of their concrete form. This means that visuals with differing forms may fulfill multiple functions and a single visual can potentially be described in terms of several functions. Secondly, just as verbal hierarchies of macro- and hyperThemes organize text by creating a flow and sense of unity, so does visual composition. The framework allows for the systematic description of relationships between verbal realizations and other graphic components such as tables, icons, and space itself. The descriptions afforded by the framework especially brought attention to the functions of headings in the infographics.

Economou's (2009) visual Appraisal is a direct development of SFL's verbal Appraisal system, and therefore naturally works with the concepts and metalanguage provided by SFL. An important aspect of this framework is the subsystem of Graduation, which provides resources for the indirect expression of visual Attitude. Several instances of visual attitudinal expression in the texts are realized by the recurrent use of graphic components (for example, the Isotype charts in Disc.1), where the single use of the visual in question may suggest a slightly different Attitude, or perhaps none at all. In such cases, the visual encoding principles of [depicting] and [repeating] are working together to realize Attitude. This also exemplifies the cooperation of Periodicity and Appraisal at the visual level.

The functional nature of the frameworks allows for their joint implementation. The notions of textual meaning and interpersonal meaning embedded in SFL's discourse systems of Periodicity and Appraisal, respectively, accordingly permeate the frameworks put forth by Engelhardt and Richards (2018) and Economou (2009). As a result of this conceptual mirroring, despite any differences in origin or terminology, the notions of Periodicity and Appraisal are strengthened. Consequently, these discourse system concepts were applied as an overarching functional framework for the entire analysis.

The analysis above shows various ways in which semiotic resources are used to carry out the functions of the discussion genre. Once again, no sweeping conclusions can be made about the genre or text type, but the analysis reveals how verbal and visual resources of Periodicity and Appraisal can be implemented to communicate a point of view.

Genre staging both influences and is expressed by discourse semantic systems (Rose 2007: 188). The conventional staging order of discussions, [Issue^Sides^Resolution], as outlined in SFL seems to be generally applicable to the texts examined here. However, one infographic (Disc.2) manifested a contrasting order, namely [Issues^Resolution^Sides]. This is an indication and reminder that genres are socially constructed, and therefore subject to variation and change (cf. Martin & Rose 2008: 259). Because argumentation, like any other genre, is a process (5.2.3), meaning in argumentative texts is constructed as the text progresses. Consequently, irrespective of the differences in individual messages, the construction of meaning in Disc.2, where the Resolution is wedged between the Issue and Sides, develops in a fundamentally different way than in either Disc.1 or Disc.3. The authors' positions in Disc.1 and Disc.3 are steadily developed through the Issue and Sides before being solidified in the Resolution. However, in Disc.2, the Sides stage fleshes out both the Issue and the Resolution, providing the substance of the author's stance. In all three infographics, the functions of each stage are fulfilled both visually and verbally, albeit to different extents.

The system of Periodicity, which describes the waves of information created in a text, is tightly intertwined with the stages and phases of a genre. These segments of meaning within a genre are signaled in a text through macro-and hyperThemes, which were identified above for each of the infographics. In all three texts, headings and subheadings are responsible for verbally establishing the waves of information. Each title functions as the highest order macroTheme for the respective infographic, creating the initial expectations for the text. In each case, the title also functions to introduce the Issue stage. Lower-order macroThemes introduce relatively large sections of text, while the label of hyperTheme is reserved for utterances that establish thematically concentrated segments.

Graphic elements heavily influence Periodicity in all three infographics, however, and are arguably equally, if not primarily, responsible for creating distinct waves of information. It is essential to bear in mind that headings and subheadings are identified as such not only by their information content, but by their placement. Graphic elements of organization, namely the spatial relationship between the headings and the information contained in the respective section, whether words, graphs or other visual components, help establish the role of the heading as a hyper- or macroTheme. For example, the titles as highest-order macroThemes function as such because they are larger than the other verbal elements and the subsequent information is positioned in such a way that makes a clear distinction. This is done in all three infographics primarily through the visual encoding principle of [grouping by boundary].

The Theme hierarchies differ significantly in length and complexity between the infographics (Figures 12, 16, 19); yet, this is reflective only of the individual nature of the texts. What is meaningful, however, is the extent to which these hierarchies create and fulfill reader expectations. In Disc.1 and Disc.3, the verbal macro- and hyperThemes as well as the consistent use of visual encoding principles establish steady, periodic waves of information, resulting in a unified package of information. In contrast, the packaging of information in Disc.2 is not as harmonious, a result of inconsistent use of visual encoding principles and deviation from expectations generated by the headings.

The configuration of Appraisal resources throughout a text is fundamental to carrying out the function of argumentation genres. Although only three texts were examined, the analysis reveals a variety of resources through which stance can be constructed. As instances of discussion, the infographics engage with more than one perspective; in this case, the extent to which GMOs can be considered ‘good’ or ‘bad’. However, as is common in discussion genres, there is a clear inclination towards one side over the other in each example, the development of which is revealed through Appraisal analysis.

Each infographic demonstrates a unique application of Appraisal resources, with one significant similarity. APPRECIATION is by far the most dominant attitude type in each infographic. This is related to the object of discussion: APPRECIATION appraises objects, phenomena, and processes; GMOs are artefacts of human processes. However, in each text, the punctuated instances of JUDGEMENT and AFFECT, both inscribed and invoked, and sometimes overlapping with each other or expressions of APPRECIATION, are responsible for generating nuanced positions. Not only does this emphasize attitudinal variation but brings attention to the targets of appraisal.

In Disc.1, both verbal and visual resources play central roles in expressing attitudinal meaning. The partiality of the author is made explicit through the repeated use of *good*, *bad* and *ugly,* in the title as well as throughout the Sides, echoing the visual asymmetry in the title illustration and establishing a pattern of imbalance in attitude polarity and intensity. The recurrent verbal and visual incorporation of negative AFFECT in the 'bad' and 'ugly' sections engages with aspects of human emotion, potentially creating a more personal connection with the reader. JUDGEMENT is implemented relatively proportionally throughout the discussion, with instances of positive and negative JUDGEMENT in support of and against GMOs, respectively. However, contrary to the typical function of JUDGEMENT as a resource to evaluate human actors and their actions, the author notably introduces JUDGEMENT to evaluate GMOs as if they were capable of conscious behavior. In doing so, the author blurs the boundaries between categories, potentially facilitating the emotional manipulation of the reader.

In Disc.2, the few instances of verbal JUDGEMENT stand in contrast to the prevalence of positive APPRECIATION. First, the JUDGEMENT directed at the audience in the Resolution further enhances the author's subsequent use of this resource. Then, the negative appraisal of GMO companies in the Sides compared to the overwhelmingly positive appraisal of potential effects of GMOs themselves creates a relatively clear-cut distinction between how the author feels the reader should view the actions of people versus the product. Visual Appraisal resources are not as prevalent in Disc.2; however, both images included in the Sides, one for each side, express negative Attitude, confusing the two perspectives and dampening optimism about GMOs.

Disc.3 exhibits yet another constellation of Appraisal resources. Visuals are hardly used for attitudinal expression here, reflecting what seems to be the author's attempt to appear objective. The larger Issue stage presents a nearly homogenous expression of positive APPRECIATION, with few exceptions. It is in the Sides where realizations of AFFECT and JUDGEMENT, along with Engagement and Graduation, generates a clearer attitudinal asymmetry, guiding the discussion in one direction over the other. The use of hedging and downscaling in presenting the case against GMOs, distances the author from the claims, ultimately revealing a willingness to engage with different points of view, although hesitant to commit to one side or the other, as indicated in the Resolution.

Working together, these discourse systems (naturally in cooperation with the other discourse systems not addressed here) work to generate the discussion genre and establish the authors' stance on GMOs. The systematic use of [grouping by alignment] to organize information as well as the attitudinal pattern in Disc.1 clearly develops the author's cautious and skeptical stance towards both GMOs themselves and actors involved. The unconventional staging and inconsistent implementation of [grouping by color] and [nesting] in Disc.2 seems to reflect the author's uncertainty, otherwise realized through unexpected attitudinal expressions with respect to the macroThemes, both verbally and visually. Finally, in Disc.3, the author's reserved and distanced stance is realized through the consistent use of visual encoding principles, relatively neutral visual tokens, and inclusion of other voices.

The identification of these patterns of meaning allow for a deeper understanding of the texts that goes beyond a simple decoding of signs. In understanding, explaining and questioning the use of semiotic resources, one acquires a greater awareness and knowledge of communicative processes. Such processes are foundational for the making and distribution of scientific knowledge as well as the negotiation and synthesis of different knowledge sources involved in decision making.

7. The CLIL connection

The concept of CLIL is a promising approach to address 21st century educational needs. With rapid advancements in technology and the consequent changes in communication, the meaning of *literacy* has broadened to encompass not only the ability to read and write, or the possession of subject knowledge, but the ability to engage with various tools and modalities as well. If the goal of literacy education is to mold students into able and active participants in society, they need to be equipped with flexible tools and skills that allow them to effectively engage in social processes.

The approach adopted to the texts above and the meanings revealed through the analysis complement CLIL's 4Cs framework and pluriliteracies focus. Figure 24 illustrates how GMO infographics could be part of a robust CLIL unit, broadly outlining components of all 4Cs. In view of the fact that subject curricula typically provide the starting point for CLIL lessons (Coyle, Hood & Marsh 2010: 53), the basis of this hypothetical CLIL unit is GMOs. This topic is also prescribed in Austrian upper secondary curricula for the natural sciences as a topic to be explicitly addressed (BMFWF 2015: 84; BMBWF 2018; BMBWF 2019: 97).

The content of a unit develops from the overarching theme. In this case, understanding the process of genetic modification as well as its uses and challenges would all be considered central content learning goals for students. Simple knowledge acquisition is not adequate, however. Equally important are the „knowledge, skills and understanding we wish our learners to access" (Coyle, Hood & Marsh 2010: 53), meaning teachers need to give students room to learn how to construct their own knowledge (Coyle 2007: 550; Meyer 2010: 12). With respect to the focus of this thesis, the ability to understand and reflect upon public science discourse, in particular as it is manifested in infographics, would define a significant portion of the content for such a unit. This could include an awareness of the various socio-scientific issues associated with GMOs, an understanding of the roles semiotic resources play in negotiating stance on the topic, and therefore an improved understanding of how GMOs are debated in the public sphere. This broadened concept of content renders the connections to the other Cs, cognition, communication and culture, more transparent.

Analyzing infographic argumentation requires students to activate and develop both lower-order and higher-order thinking skills, both of which are necessary for effective CLIL (Coyle, Hood & Marsh 2010: 54). The argumentation genre, specifically discussion, serves here as a tool with which such desired cognitive processes can be defined (Morton 2010: 99). Examples of relevant lower-order thinking skills would be identifying the genre and recognizing its purpose, describing the societal domains that factor into the discussion, and applying the Richards-Engelhardt framework to classify the visual encoding principles implemented by the authors. Analysis and evaluation of the infographics would be instrumental in developing higher-order thinking skills; for instance, deconstructing texts according to metafunction and/or semiotic mode in order to differentiate how these elements of meaning and meaning-making contribute to the text's purpose, its genre. This could, in turn, lead to reflection and critique of the effectiveness of various elements in the text and the text as a whole. These processes emphasize reading as a constructive process beyond word recognition, and they are tightly intertwined with an understanding of language.

With a focus on developing a fundamental sense of scientific literacy, the communication component of the 4Cs is crucial in this scenario. Language is not only a tool for communication, but a tool for integrating cognitive skills so that content can be learned (see 2.2.). Following the language triptych (Figure 2), there are several aspects of language applicable to understanding these GMO infographics. As genetic engineering is typically scheduled for students' last or second to last year of secondary education (BMFWF 2015: 84; BMBWF 2018; BMBWF 2019: 97), students should have acquired at least basic vocabulary for describing numerical relationships, the relative placement of textual components, and expressing intention (BMFWF 2015: 30-37; BMBWF 2018; BMBWF 2019: 31-35). Without this vocabulary, understanding and acquisition of language for learning will be challenging. Content vocabulary, such as key terms in genetics and ecology (e.g. *genes, trait, resistance*), is also included here.

Language for learning encompasses metalevel thinking, an aspect strongly emphasized in CLIL (Coyle, Hood & Marsh 2010: 62). Metalanguage, as mentioned in section 3.5.1., is important for the development of critical literacy. It is a tool with which one can create distance from familiar linguistic structures; a distance necessary in order understand the how and why language functions the way it does (Llinares, Morton & Whittaker 2012: 111). It provides access to abstract concepts, which, in turn, fosters the development of cognitive processes, symbolized by the arrows in Figure 24. It is with metalanguage that knowledge about systems of language, texts, and genres can be developed (Morton 2010: 100; Unsworth 2001: 8).

In the present context, this language for learning includes the analytical tools for examining the verbal and visual resources of meaning-making. SFL provides a rich and comprehensive metalanguage for describing functional aspects of language; likewise, Engelhardt and Richards (2018) provide a clear nomenclature for describing graphic relationships. The implementation of metalanguage is accompanied by its own challenges, however. It takes time and effort for teachers and students to become familiar with the relevant terms. While an analysis like the one above may be challenging or unrealistic for secondary science teaching, and metalanguage may need to be selectively implemented, the concepts of Periodicity and Appraisal are very much relevant to scientific literacy goals.

A systematic approach can help students develop metaknowledge about science and culture by revealing nuances in the composition of argumentation and in the perception of science in the public sphere. Explicit knowledge of the construction of texts and the individual reconstruction of a text through reading can give students practical real-world skills for responsible citizenship. Principles of textual organization, verbal or visual, influence how a text is read. Simply identifying the organizational components and principles at work in multimodal texts like infographics already establishes distance to the text. Knowledge of the function of macro- and hyperThemes, whether or not this specific metalanguage is implemented, allows the reader to contemplate the author's position as a creator. Combined with a reflection of one's personal reaction to the text, conscious attention to these elements can not only encourage students to read critically, supporting fundamental literacy skills (see 3.5.2.), but contribute to their own conscious text design practices.

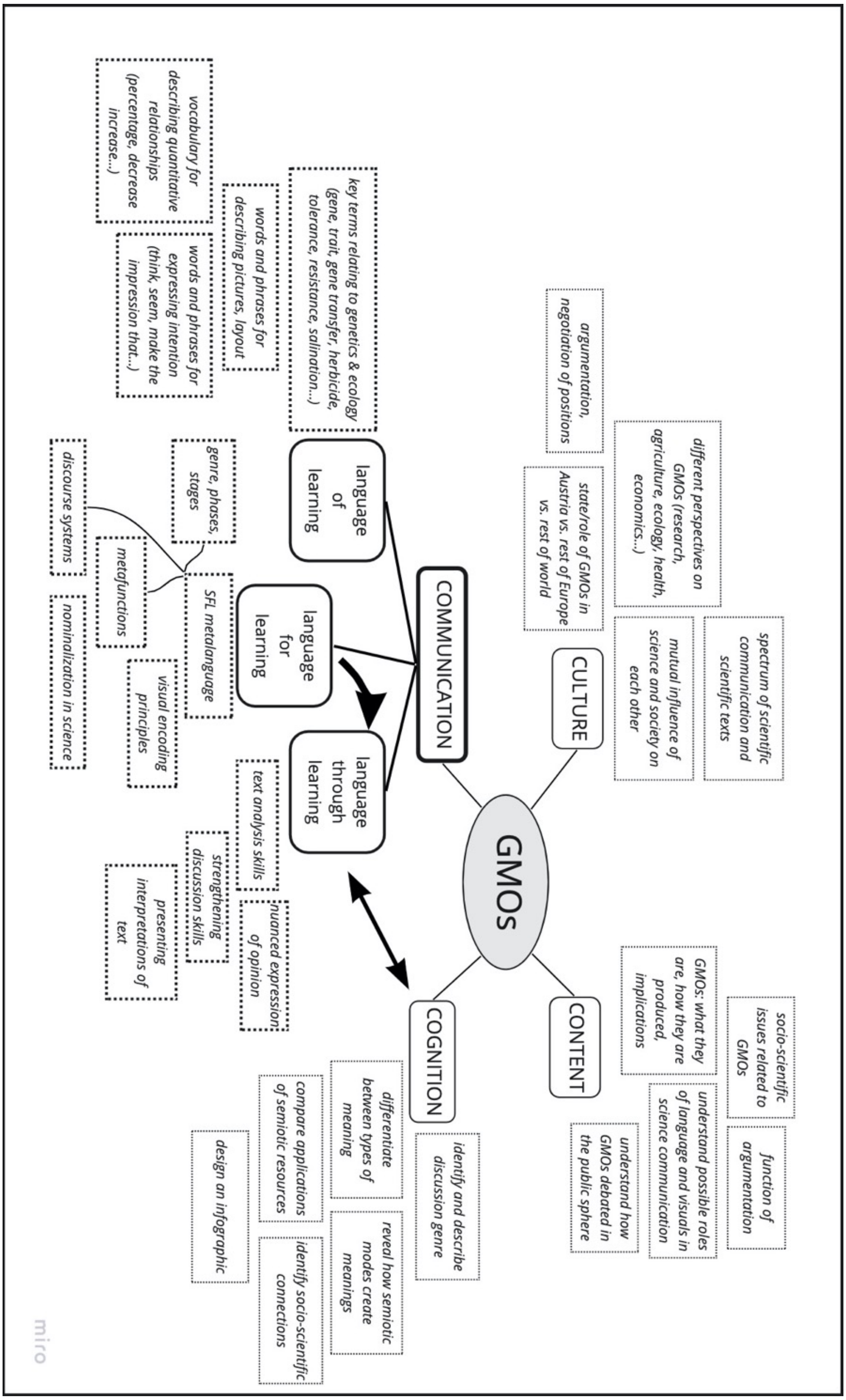

Figure 24: GMO infographics and the 4Cs.

Similarly, deliberate attention to how opinions are expressed create awareness of the relationship science has with society and its role as an integral part of society. Analysis of the meaning-making resources used in any science text is simultaneously an engagement with the norms, values, and various interests involved in scientific knowledge. In distinguishing between types of attitudes, one opens up ample opportunity to address the various facets of a controversial issue like GMOs. Systematic deconstruction of authors' intention and stance makes the nuances of the text construction accessible to students, giving them the tools to construct their own knowledge about the issue. Perhaps most importantly, explicit knowledge about and interaction with meaning-making resources provides students with a point of departure for further inquiry.

These aspects of language are also closely related to the final C, culture. Culture not only stands as its own essential component of CLIL, but permeates the other three Cs as well. Learning about genetic engineering is learning about scientific culture; learning about non-scientific perspectives on scientific issues is learning about culture; learning how to interact with a genre is learning about culture, as genres are cultural artifacts; and in learning how to apply higher-order cognitive skills, which reflects the type of thinking used in the discipline, is learning about culture.

The core components of CLIL can help guide the implementation of popular science texts in science education. Not only are they authentic, accessible sources of information, but in using the 4Cs as a guide, they offer an abundance of opportunities to foster active engagement with the texts. CLIL's emphasis on language brings attention to how the use of semiotic resources shapes our understanding of our world, an understanding which is critical for scientific literacy.

8. Conclusion

This thesis aimed to create explicit connections between science and society, content and language, and verbal and visual modes of communication. Recognizing the overlap between traditional categorical boundaries is increasingly necessary in order to prepare students for the dynamic nature of 21st century life. Science educators must therefore reconsider the status of traditional scientific knowledge as sufficient for students to become scientifically literate citizens.

While scientific literacy may be challenging to define, a key aspect of any approach to literacy is the ability of an individual to seek, understand, and use information. Average citizens do not turn to original scientific publications; instead, popular science media such as television and the internet supply the majority of their information. Students may be familiar with the practicalities of today's digital technology, but this does not bestow them with the ability to critically engage with these media or the content they encounter. Original notions of literacy as the ability to read and write are applicable for scientific literacy, too, for the comprehension of scientific concepts and culture are often linked with various textual productions.

This inquiry into discussion in GMO infographics enables engagement with the three areas of integration mentioned above while supporting a fundamental sense of scientific literacy. Argumentation is integral to scientific practices within expert communities, between expert and non-expert communities, and between interest groups outside scientific circles. Argumentation is a social, communicative process for which language is essential. As a relatively new and controversial area of science, genetic modification provides an opportunity to explore discussions on the topic, exposing how GMOs are intricately connected to a range of societal domains. Infographics, as multimodal, ubiquitous and accessible online texts, not only bring attention to modern forms of communication but provide a canvas for exploring multimodal meaning-making.

Reading texts requires the negotiation of semiotic resources. This thesis sought to investigate how the authors used both verbal and visual resources in their argumentation, specifically the extent to which such means were utilized to organize meaning and express attitude. To do this, analytical tools from SFL's discourse semantics, Engelhardt and Richard's (2018) visual encoding principles, and Economou's (2009) visual Appraisal were applied. The adoption of SFL notions of Periodicity and Appraisal as an overarching framework to examine the verbal and visual implementation of organizational and attitudinal resources enabled a partial account of how the respective authors construct a discussion on the benefits and drawbacks of GMOs. Notwithstanding the limited number of texts, this work offers a glimpse of the affordances of this combination of frameworks as well as valuable insights into the nuances that can be uncovered through systematic analysis.

This analysis only scratches the surface, however. For students to reap the benefits from such an investigation, they must internalize the concepts and process. They must possess appropriate metalanguage that allows them to access texts' implicit meanings. A holistic educational approach like CLIL brings attention to the often neglected linguistic aspects of content knowledge. Going forward, investigations into other types of infographics using these frameworks could further expose the affordances of these frameworks. Additionally, students should have opportunities to create and analyze their own infographics, bringing awareness to their own semiotic choices. If students are not equipped with tools to actively and critically engage with multimodal socio-scientific texts, they may be deprived of the ability to become fully-fledged participants in society.

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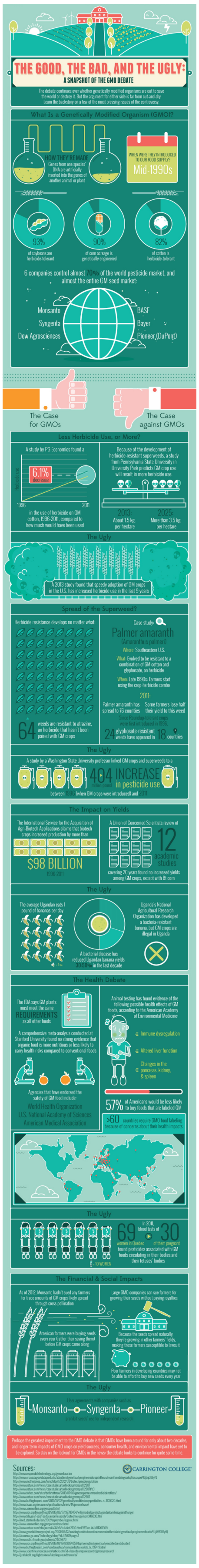
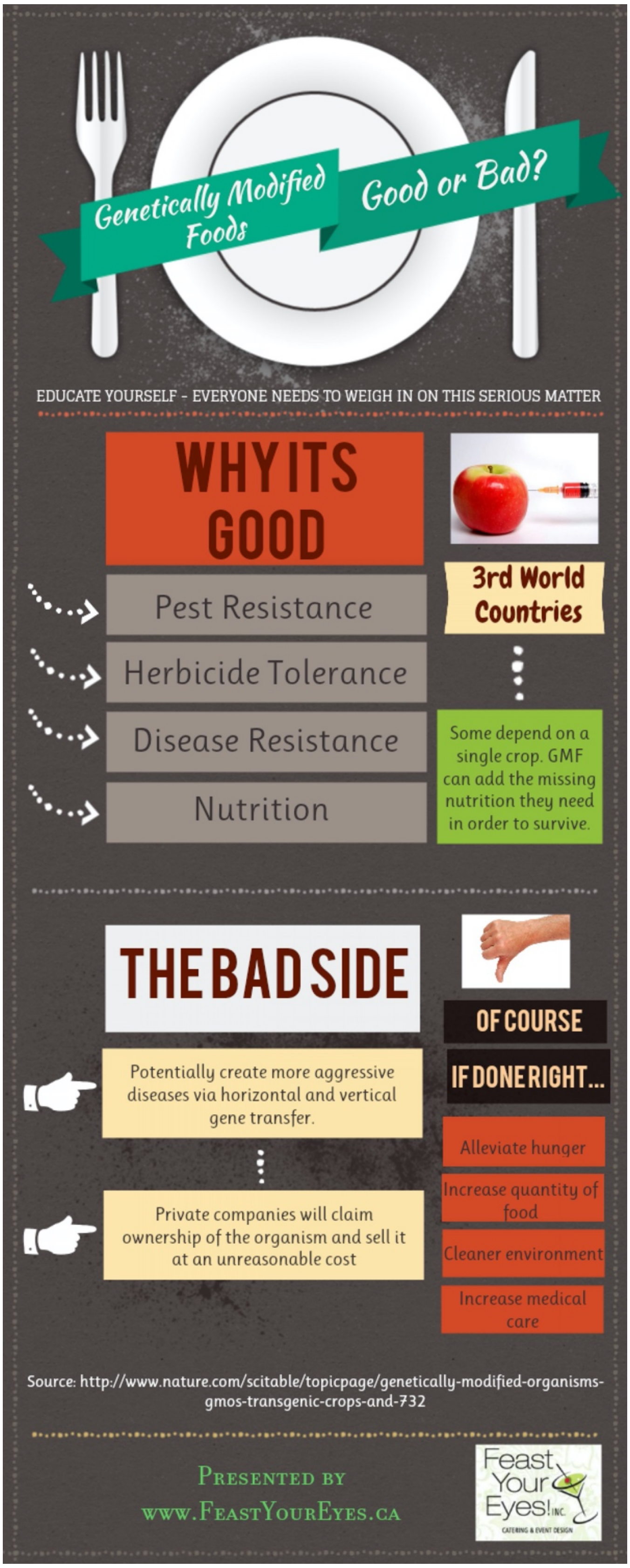
10. Appendix

10.1. The good, the bad, and the ugly: a snapshot of the GMO debate

See page 125


THE GOOD, THE BAD, AND THE UGLY:
A SNAPSHOT OF THE GMO DEBATE
The debate continues over whether genetically modified organisms are out to save the world or destroy it. But the argument for either side is far from cut-and-dry. Learn the backstory on a few of the most pressing issues of the controversy.
What Is a Genetically Modified Organism (GMO)?
HOW THEY'RE MADE
Genes from one species' DNA are artificially inserted into the genes of another animal or plant
WHEN WERE THEY INTRODUCED TO OUR FOOD SUPPLY?
Mid-1990s
93%
of soybeans are herbicide-tolerant
90%
of corn acreage is genetically engineered
82%
of cotton is herbicide-tolerant
6 companies control almost 70% of the world pesticide market, and almost the entire GM seed market:
Monsanto
Syngenta
Dow Agrosciences
BASF
Bayer
Pioneer (DuPont)
The Case for GMOs
The Case against GMOs
Less Herbicide Use, or More?
A study by PG Economics found a
Herbicide use
6.1% decrease
1996
2011
in the use of herbicide on GM cotton, 1996-2011, compared to how much would have been used
Because of the development of herbicide-resistant superweeds, a study from Pennsylvania State University in University Park predicts GM crop use will result in more herbicide use:
2013: About 1.5 kg. per hectare
2025: More than 3.5 kg. per hectare
The Ugly
A 2013 study found that speedy adoption of GM crops in the U.S. has increased herbicide use in the last 9 years
Spread of the Superweed?
Herbicide resistance develops no matter what:
64 weeds are resistant to atrazine, an herbicide that hasn't been paired with GM crops
Case study:
Palmer amaranth
(Amaranthus palmeri)
Where: Southeastern U.S.
What: Evolved to be resistant to a combination of GM cotton and glyphosate, an herbicide
When: Late 1990s: Farmers start using the crop-herbicide combo
2011:
Palmer amaranth has spread to 76 counties
Some farmers lose half their yield to this weed
Since Roundup-tolerant crops were first introduced in 1996,
24 glyphosate-resistant weeds have appeared in 18 countries
The Ugly
A study by a Washington State University professor linked GM crops and superweeds to a
404 million-pound INCREASE in pesticide use
between 1996 (when GM crops were introduced) and 2011
The Impact on Yields
The International Service for the Acquisition of Agri-Biotech Applications claims that biotech crops increased production by more than
$98 BILLION
1996-2011
A Union of Concerned Scientists review of
12 academic studies
covering 20 years found no increased yields among GM crops, except with Bt corn
The Ugly
The average Ugandan eats 1 pound of bananas per day
= 1 oz.
A bacterial disease has reduced Ugandan banana yields 30-50% in the last decade
Uganda's National Agricultural Research Organization has developed a bacteria-resistant banana, but GM crops are illegal in Uganda
The Health Debate
The FDA says GM plants must meet the same REQUIREMENTS as all other foods
A comprehensive meta-analysis conducted at Stanford University found no strong evidence that organic food is more nutritious or less likely to carry health risks compared to conventional foods
Agencies that have endorsed the safety of GM food include:
World Health Organization
U.S. National Academy of Sciences
American Medical Association
Animal testing has found evidence of the following possible health effects of GM foods, according to the American Academy of Environmental Medicine:
Immune dysregulation
Altered liver function
Changes in the pancreas, kidney, & spleen
57% of Americans would be less likely to buy foods that are labeled GM
>60 countries require GMO food labeling because of concerns about their health impacts
The Ugly
In 2011, blood tests of
69 women in Quebec
30 of them pregnant
found pesticides associated with GM foods circulating in their bodies and their fetuses' bodies
= 10 WOMEN
The Financial & Social Impacts
As of 2012, Monsanto hadn't sued any farmers for trace amounts of GM crops likely spread through cross-pollination
American farmers were buying seeds every year (rather than saving them) before GM crops came along
Large GMO companies can sue farmers for growing their seeds without paying royalties
Because the seeds spread naturally, they're growing in other farmers' fields, making these farmers susceptible to lawsuit
Poor farmers in developing countries may not be able to afford to buy new seeds every year
The Ugly
User agreements with companies such as
Monsanto
Syngenta
Pioneer
prohibit seeds' use for independent research
Perhaps the greatest impediment to the GMO debate is that GMOs have been around for only about two decades, and longer-term impacts of GMO crops on yield success, consumer health, and environmental impact have yet to be explored. So stay on the lookout for GMOs in the news: the debate looks to continue for quite some time.
CARRINGTON COLLEGE

10.2. Genetically modified foods: good or bad?



10.3. What do you know about GMOs?

Abstract

The increasingly digital and multimodal nature of the modern world requires teachers to prepare students to critically engage with the plethora of information they will encounter in their adult lives. A holistic educational approach like CLIL (content and language integrated learning) can guide science teachers to concentrate not only on the acquisition of content, but the development of cognitive skills, communicative competencies, and cultural awareness, all needed in 21st century life. The concept of scientific literacy must therefore also be expanded to include reading skills and societal connections, as science cannot be separated from either language or culture. GMO infographics, as easily accessible, multimodal popular science texts, serve as an ideal object of analysis. Through the examination of both visual and verbal realizations of organizational and attitudinal resources, this thesis uncovers different ways in which discussions on a controversial scientific concept such as GMOs are constructed in the public sphere. Furthermore, it addresses how these discussions are relevant to scientific literacy.

In einer immer stärker digitalisierten Welt mit ihrem Überangebot an Informationen ist es entscheidend, SchülerInnen auf den Umgang mit Inhalten vorzubereiten. Ein ganzheitlicher Unterrichtsansatz wie CLIL (*content and language integrated learning*) hilft Lehrenden, ihren SchülerInnen nicht bloß Inhalte, sondern kognitive Fähigkeiten, Kommunikationskompetenzen und kulturelles Bewusstsein, wie in der modernen Gesellschaft des 21. Jahrhunderts benötigt, zu vermitteln. Wenn wir über naturwissenschaftliche Grundbildung (*scientific literacy*) sprechen, dann muss die Diskussion auch Lesefähigkeiten und soziale Konnotationen miteinschließen, denn Wissenschaft kann weder von Sprache noch von Kultur getrennt betrachtet werden. Infografiken über gentechnisch veränderte Organismen (GVOs) sind leicht zugängliche, multimodale Wissenschaftstexte und stellen daher einen idealen Forschungsgegenstand dar. Indem sowohl visuelle als auch verbale Praktiken auf organisationaler und einstellungsbildender

Ebene betrachtet werden, diskutiert diese Abschlussarbeit verschiedene Möglichkeiten, wie ein kontroversielles wissenschaftliches Thema wie GVOs in der öffentlichen Meinung konstruiert wird. Außerdem wird eine Verbindung zwischen diesen Möglichkeiten und ihrer Relevanz für die *scientific literacy* hergestellt.