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This is not a Pipe: Incorporating Art in the Science Curriculum*

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Abstract

Science courses employ instructional strategies that are based on lecture, drill, and practice to help students memorize collections of facts and procedures of increasing complexity. These strategies emphasize the acquisition of knowledge through the development of logical-mathematical skills employed in problem solving and verbal-linguistic abilities to make sense of the concepts and jargon in the field. Due to its highly abstract character, these science courses deal with complex representations that require an understanding of the role of mental models. Learners need to develop their visual-spatial skills as a means of gradually acquiring visual literacy while grappling with the symbols and conventions displayed in the figures, diagrams, and charts in textbooks. The Art & Science Project started at Vanier College as part of the History of Science course in the liberal arts program and was later adapted for use in three core chemistry courses (General, Solution, and Organic Chemistry) in the science program. The project uses a cross-disciplinary integration between visual arts and the natural sciences to promote a deeper understanding of the role of models. The liberal arts students analyze the parallels between the evolution of modern scientific concepts and the art movements from the same historical periods. Science students create visual representations that portray core ideas and threshold concepts in the field. The goal is to portray these abstractions using visual arts as means of creating meaning through symbolic visual representations while developing new perceptions of visual forms.

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The decline in science literacy among the general population undermines citizens' ability to understand basic scientific principles and hinders the development of personal and political awareness, both of which are necessary to make rational decisions. For example, it is paramount to effectively participate in the political debate regarding the choices that can be made collectively which will impact the environment and the sustainability of our society in the long term. In the last few decades, the decrease in the number of science students in industrialized countries (Broman, Ekborg, & Johnels, 2011; Convert & Gugenheim, 2005; Potvin & Hasni, 2014) is another trend that can be associated with the declining interest in science (Hoffmann, 2012; Lyons, 2006). In a time when creative professionals with solid knowledge of the complexity and intricacies of scientific research are in demand, the dwindling number of science students has become a serious threat to keeping up with the current technological innovations that require professionals with specific training in key sectors such as information technology (Ali & Shubra, 2010; Xue & Larson, 2015), health (Nair & Webster, 2010), and education (Logan & Skamp, 2013; Venville, 2008). To reverse this trend, finding ways to attract students to science programs has been a major issue in recent science education reforms in both North America and Europe (Atkin & Black, 2003; Pea & Collins, 2008).

By addressing pedagogy and learning, the research in science education has explored new styles of teaching with the aim of enhancing learning and sparking students' interest in the field. There has been a shift from traditional, teacher-centered approaches that are focused on content (Bunce, 2009; Duit & Treagust, 1998; Ramsden, 2003) to student-centered pedagogies whose focus is on the learning process (Bodner, Gardner, & Briggs, 2005; Fosnot & Perry, 2005; Mortimer & Scott, 2003; Quintana, Shin, Norris, & Elliot, 2006; Taber, 2000; Weimer, 2002). This change in perspective has been guided by studies in cognitive psychology that analyze mental processes including how people think, perceive, remember, and learn (Bransford, Brown, & Cocking, 2000; DeJong, et al., 2009; Heath & Gilbert, 2015; Hussein & Reid, 2009; Reif, 2008).

Although the traditional one-size-fits-all teacher-centered models (Kalantzis & Cope, 2008) are easy to construct and to manage (Wink, 2005), their focus is on the delivery of the material (Blackie, Case, & Jawitz, 2010). These traditional views of education envision learning merely as a series of steps to be mastered and use standardized tests to close achievement gaps across the system by emphasizing order, control, and conformity (Kvale, 2007). Within this context, the use of standardized exams offers an efficient process which is part of a "line of bureaucratic command" (Kalantzis & Cope, 2008, p. 214) to fulfill the requirements of accountability from students to professional bodies and government stakeholders. Instead of traditional assessments *of* learning, student-centered pedagogies require the development of authentic assessments *for* learning (Fink, 2003), whose development has become a goal in science education reforms (Atkin & Black, 2003; DeBoer, Lee, & Husic, 2008; Kalantzis & Cope, 2008). Considering the fast changes in our increasingly interconnected world and its knowledge-based economy, recently developed learning environments have aimed to support all students by recognizing their individual differences in terms of attitudes, interests, and life experiences (Bretz, 2005; Tate, Clark, Gallagher, & McLaughlin, 2008).

From the perspective of curriculum development, the old premise that the main goal of science education is the transmission of information has been replaced with a remarkably different view in which knowledge is no longer a mere collection of facts that need to be acquired but rather consists of interrelated concepts—mental categories or abstract notions—that encompass truths, information, and principles that enable a person to construct meaning about the world (Bodner et al., 2005; Wink, 2001). Within this new framework, the role of the teacher is to facilitate this construction by organizing appropriate classroom activities (Cracolice, 2005; Fink, 2003; Krajcik, Slotta, McNeill, & Reiser, 2008; Novak & Gowin, 1984; Wiggins & McTighe, 2005) with the aim of promoting teaching for understanding (Gardner & Boix-Mansilla, 1994; Mintzes, 2007; Taber, 2005; Weaver, 2009), which is associated with students' ability to transfer knowledge. To accomplish this, instructors promote debate among students in class triggered by "asking simple questions dealing with simple concepts" (Mazur, 2005). Replacing the traditional lecture format (Geiger, Jones, & Karre, 2009), peer instruction is an instructional strategy in which students transfer knowledge through a process of discovery that is mediated by social interactions that involve refining and discussing information from different perspectives (Brooks & Koretsky, 2011; Cooper, 2005; Coppola & Pontrello, 2014; Mazur, 1997; Moog & Farrell, 2011; Varma-Nelson & Coppola, 2005). At the post-secondary level, this innovative approach has become the basis of active-learning pedagogies (Bean, 2011; Drane, Micari, & Light, 2014; Freeman, et al., 2014; Parkinson, 2009), which have received a great deal of attention since the 1990s.

In the last few decades, the idea of integrating subject areas in schools has also become quite popular among educators, and it is one of the hallmarks of the curriculum changes proposed in recent science education reforms (Atkin & Black, 2003; Krajcik, Slotta, McNeill, & Reiser, 2008) as an attempt to enhance students' interest in science. Multidisciplinary project-based learning environments select topics that fall outside the traditional disciplines such as health, food and agriculture, energy, water, mineral resources, and the environment (Hassard & Dias, 2009; Schwartz-Bloom, Halpin, & Reiter, 2011) to promote critical thinking (Herreid, Schiller, & Herreid, 2012). While recognizing the necessity of continuing to learn from individual disciplinary perspectives, scholars have pointed out that curriculum integration has the potential of helping students learn to look at problems from different perspectives, think critically, and be better equipped to interact with real-life situations (Beane, 1997; Czerniak, 2007; Donald, 2002; Gardner, 2001; Gardner & Boix-Mansilla, 1994). In higher education, these skills have become especially critical in cutting-edge fields such as nanotechnology and artificial life, whose disciplinary areas encompass chemistry, biology, physics, engineering, mathematics, and computer science.

Relevant learning experiences that engage students academically and emotionally are transformative processes whose premises involve a high degree of coherence and alignment among four basic dimensions: students' pre-knowledge and interests, instruction, curriculum, and assessment (Fink, 2003; Roseman, Linn, & Koppal, 2008; Weimer, 2002; Wiggins & McTighe, 2005; Wink, 2005). In an era dominated by standardization (Lake, 2013), enhancing science literacy among the general population might require bold adjustments in terms of restructuring the curriculum (Cooper & Klymkowsky, 2013; Talanquer, 2013) and exploring the roles of creativity and imagination in learning (Bianchi, 2014; Egan & McKellar, 2010; Robinson & Aronica, 2015).

This paper addresses both issues while describing the conceptual framework of the *Art & Science Project*, a project which has been conducted at Vanier College since 2009 with the goal of enhancing the learning of scientific concepts by incorporating art history and art making in the curriculum (Lima, 2016).

Art in the Science Curriculum

In his seminal work, *The Educated Mind – How Cognitive Tools Shape Our Understanding*, Egan (1997) offers a critique of the models of instruction whose hallmark is standardization and where disciplines "are often taught as having a nature to which the child has to conform" (p. 216). As an alternative to this framework, the author recommends seeking accommodation by exploring intellectual tools that enable the child to engage with the "nature" of the discipline. He suggests using art making to encourage learners to explore the material by engaging with it through their senses.

The inclusion of art in the curriculum can also help to achieve the integration of knowledge with both the humanities and the natural sciences. This integration enriches students' cultural development by contextualizing the evolution of both artistic expression and scientific concepts against the backdrop of historical and philosophical perspectives (Efland, 2002; Lerman & Morton, 2009; Reichle, 2015; Tani, Juuti, & Kairavuori, 2013; Ward, 2015). Aside from its inherent active-learning nature, which characterizes student-centered pedagogies, engaging in hands-on activities to create visual art products or just exposing students to exercises of aesthetic contemplation have been shown to promote gains in cognition (Efland, 2002; Eisner, 2002; Gardner, 2006; Heath & Gilbert, 2015; James & Brookfield, 2014). Exploring art as a tool for learning science has been the subject of several studies at the K-12 level (Egan & McKellar, 2010; Gardner, 1990; Greenberg & Patterson, 2008; Halpine, 2004; Hartle & Jaruszewicz, 2009; Meyer, et al., 2013; Paige & Whitney, 2008) and, to a lesser extent, in higher education (Bopegedera, 2005; Furlan, Kitson, & Andes, 2007; Halpine, 2008; Lunn & Noble, 2008; Welch & Fasano, 2016).

Directly linked to the arts, the role of creativity in education has been extensively reported in the recent literature (Gardner, 1993; Kaufman & Baer, 2006; Lobman, 2010; Nygaard, Courtney, & Holtham, 2010; Sawyer, 2012; Weisberg, 2006). With over 49 million viewers so far, Robinson's (2006) TED Talk, *Do Schools Kill Creativity?*, offers a critique of traditional schooling by emphasizing the necessity of rethinking a system that has historically valued the arts as less than math and the natural sciences. The project presented here has received inspiration primarily from the ground-breaking works of Egan (1997; 2005; 2007), Robinson (1999), and Csikszentmihalyi (1997), which have brought awareness of the historically neglected potential of imagination and creativity in education. It also incorporates relevant aspects of social constructivism (Fosnot & Perry, 2005) by envisioning knowledge construction as a collaborative process mediated by social interactions. The concept of Vygotsky's Zone of Proximal Development (DelRio & Álvarez, 2007; Holzman, 2010; Wass & Golding, 2014) has been also taken into account when attempting to align the course activities and assessments with the current level of students' intellectual development.

The Art & Science Project at Vanier College

Located in Montreal, Canada, Vanier College is an English-language public college that offers both two-year pre-university programs and three-year technical programs with an enrolment of over six thousand students. It is part of the college's mission statement "to provide a life-enriching learning experience that prepares students to succeed academically and professionally as engaged citizens of the world." It also states that "as a college, we believe in and cultivate creativity, critical thinking, and excellence" (Vanier College, n.d.).

Lima, one of the authors of this article, holds a doctorate in chemistry from the University of São Paulo, Brazil, and has been teaching chemistry to science students in both pre-university and career programs for the past 17 years. Since 2009, he has also taught *History and Methodology of Science*, a mandatory course in the last semester of Vanier's liberal arts program. When compared to students in pre-university Science cohorts, the profile of most liberal arts students is noticeably different: they have limited backgrounds from high school science courses and a generalized lack of interest in the natural sciences. Most of these students have phobias for mathematical formulas and calculations and do not see the purpose of having a mandatory science course as part of their program. In a way, the group's profile resembles that of disengaged high school students that would never consider a career in science as a viable option for them. From the very start, finding ways to spark students' curiosity and imagination in this course became the main challenge since it was evident that the approaches that had been used with science cohorts were not well suited to liberal arts students.

Egan (2005) underlines that "instead of thinking of our lessons and units as sets of objectives we hope to attain, we can think of them as good narratives with which we hope to engage students' imaginations and emotions" (p. 99). The author also emphasizes the importance of the *humanization of knowledge* "to make it accessible, placing it in realistic environments—even if it is the dramatic, exotic, or extreme features of the real world that appeal to students' imaginations" (Egan, 2005, p. 109).

In the History of Science course, the proposed narrative links students' previous knowledge in philosophy, history, and art with the content of the science course by comparing and contrasting the evolution of the representations in visual arts with the contemporary changes in scientific paradigms since the beginning of the modern era. After a careful examination of the literature in the field, underlying patterns that connect the visual arts and natural sciences emerge. For example, during the European Renaissance, Aristotelian cosmology was challenged by Galileo's experiments in kinematics (Crowe, 2007; Machamer, 1998; Matthews, 2000), which in turn paved the road to the supremacy of Newtonian cosmology until the late 19th century (Fara, 2009; Gleick, 2003; Simonyi, 2012). During this extended period, the generalized belief that scientific knowledge described physical reality influenced the style of artworks, which utilized a realistic approach to depict an objective world consisting of well-defined and recognizable figures in three-dimensional space (Shlain, 1991; Szamosi, 1986). The depiction of the world as objective reality changed abruptly in both art and science at the beginning of the 20th century with the development of quantum theory and impressionism which "explicitly forced the viewers' perceptual experience away from reality and toward the imaginary" (Kandel, 2012, p. 215). Emphasizing the similarities between the paradigm changes in both scientific concepts and artistic forms of expression became the centerpiece of the upgraded liberal arts science course.

The curriculum developed both in- and out-of-class activities designed to help students engage imaginatively and emotionally with the content by using narrative, images, and the humanization of knowledge. Works of art of the period are used to contextualize and integrate the different disciplines—physics, chemistry, and the visual arts. Learners identify the similarities and differences between the intentions of artists and scientists in their process of creation of artworks and scientific theories. Exposing students to those analogous, and yet diverse, ideas that emerged during a particular historical period create a mosaic that is analyzed through a multidisciplinary perspective in which art and science are complementary manifestations of the human ingenuity to construct meaning of the world.

Einstein meets Monet, Magritte, and Picasso

The following are some examples of similar concepts that have emerged from artistic works and scientific models. These ideas are presented with the goal of contrasting the general views from both fields.

Up until mid-19th century, "Western art had traditionally portrayed the world in a three-dimensional perspective, using recognizable images in a familiar way" (Kandel, 2016, p. 5). The prevalent idea was that painting should either faithfully represent reality or present an idealization of reality (Shlain, 1991; Szamosi, 1986). This view went hand in hand with the conceptual framework of "Newton's orderly law-governed cosmos" where "everything could, in principle, be reduced to straightforward mathematical formulae" (Fara, 2009, p. 144). "Scientific knowledge was assumed to be a mirror image of objective reality" (Sexton, 1997, p. 7). This traditional view in the arts was refuted when artists started to "show us the world in a complete unfamiliar way, exploring the relationships of shapes, spaces, and color to one another" (Kandel, 2016, p. 5). Monet's paintings are good examples of this rupture in which the representation of the world no longer consists of well-defined and recognizable figures in three-dimensional space. Instead of focusing on the geometry of shapes, Monet eliminates the outlines and boundaries so that objects are no longer clear-cut and solid. The artist tries to capture on canvas the very act of perceiving nature by showing how light changes our visual experience. He was the first artist to immerse the viewer in the delight of color for color's sake by painting the same theme under different lighting and weather conditions. No two paintings of even the same subject look alike (Leibowitz, 2008).

By 1900, there was consensus that light and heat travels as waves. However, the wave theory of light did not explain why a small amount of electricity is produced upon shinning a bright light on some metals—the so called photoelectric effect. In 1905, Albert Einstein, the most iconic scientist of the 20th century, wrote a revolutionary paper that proposed a solution for the conundrum: in this experiment, light comes in little packets that are called *photons* (Feynman, 1995). The wave-particle duality of light—a behavior also observed with matter later—became one of the ground-breaking concepts in quantum theory. At the atomic level, Classical Newtonian mechanics does not apply and is unable to predict the behaviour of matter and the unexpected experimental results (Gamow, 1966; Greene, 2004). "In the subatomic realm of quantum mechanics, nothing is known for certain in advance—there are only probabilities" (Fara, 2009, p. 303).

In Einstein's words:

> But what is light really? Is it a wave or a shower of photons? … At that time there was every reason for discarding the corpuscular theory of light and accepting the wave theory, which covered all phenomena. Now, however, the problem is much more complicated. There seems no likelihood of forming a consistent description of the phenomena of light by a choice of only one of the two possible languages. It seems as though we must use sometimes the one theory and sometimes the other, while at times we may use either. We are faced with a new kind of difficulty. We have two contradictory pictures of reality; separately neither of them fully explains the phenomena of light, but together they do! (Einstein & Infeld, 2008, pp. 262-263)

In addition to their remarkable imaginations, Claude Monet and Albert Einstein also shared their obsessive interest in understanding and exploring the properties of light. The revolution in Monet's art was in step with the development of modern physics' radical change of worldview at the same time. We do not know what light is, only how it behaves: as a wave in some experiments and as a particle in others (Falk, 2002). Both the artist and the scientist revolutionized their respective domains by recognizing the fundamental role of the transitory character of human perception in the construction of reality. The limitations of human perception trump the desire to describe the world objectively, as was done prior to the 20th century, by emphasizing the construction of reality rather than its discovery (Hofstadter, 1999; Sexton, 1997). A true revolution had started.

The works of the Belgian painter René Magritte are used in this course as illustrations of the notion of symbolic representation (Umland, 2013). Magritte's paintings frequently portray ordinary objects that are juxtaposed in unconventional, unexpected contexts that lead viewers to new interpretations that are somewhat disruptive to consider (Heid, 2008). His iconic masterpiece *The Treachery of Images* (1929) depicts a pipe with the disclaimer "this is not a pipe," which emphasizes the distinction between objects and their representations (Sylvester, 2009). "As he plays with representation, labelling, counterfactuality, he plays with the limits of our interpretation of semantic association" (McNeil & Flett, 1999, p. 98). *In The Human Condition* (1934), a painting within the painting perfectly captures the scene behind it, which is paradoxical because the image can never equal reality (Meuris, 2004; Wargo, 2002). Students associate the ideas portrayed in these paintings with the scientific concepts of the historical period. For example, all atomic models that are studied throughout the course are only representations of aspects of an atom and neither the atom itself nor its true nature (Park & Light, 2009; Pullman, 1998). It might look obvious to an expert, but this realization helps students understand the high level of abstraction of scientific models and gives them an appreciation for the images, symbols, and conventions used in science (LaDue, Libarkin, & Thomas, 2015; Stieff, 2013).

The course also established links between the works of Sigmund Freud, Pablo Picasso, and Albert Einstein, extraordinary individuals who made their breakthroughs during the first decade of 20th century. Published in 1900, Freud's *The Interpretation of Dreams* describes the crucial role of the unconscious in determining human behavior by placing emotions and sensations as more important than rational thought (Panek, 2004).

> Freud challenged traditional beliefs that human beings are born with a specific personality. He also removed the unity of an individual's psyche, setting up a model based on ambivalence, in which concealed memories, desires, and feelings of guilt result in contradictory behaviour and conflicting emotions. (Fara, 2009, p. 300)

In 1905, Einstein published a series of revolutionary papers, including one on the Special Theory of Relativity as well as the above-mentioned paper on the photoelectric effect. These papers challenged the core scientific paradigms of Classic Newtonian Physics by reconceptualizing the basic notions of time, space, matter, light, and energy (Einstein & Infeld, 2008; Greene, 2004; Kern, 2003). During the same period, Picasso began experimenting with deconstructing physical forms to portray the world away from realistic representations to abstractions. This innovative approach resulted in his 1907 creative breakthrough *Les Demoiselles d'Avignon*, which is one of the most important paintings of the 20th century (Gardner, 1993).

> There was no attempt to represent reality faithfully or to idealize it in Les Demoiselles d'Avignon; those women are painted as they are because Picasso wanted the viewer to respond to them in a certain way. Picasso's painting mirrors his conception of those women, not his perception. This reliance upon the painter's conception in a painting, presented through visual means, was what made it so new. (Weisberg, 2006, p. 229)

By analyzing the works of these extraordinary individuals, students begin to get hold of the Zeitgeist—the spirit of the time—present at the dawn of the 20th century and to understand that neither art nor science evolve in isolation, but they are rather umbilically connected as part of the collective human mindset and experience. Science and art would never be the same after these revolutions changed our view of reality (Kandel, 2012; Kern, 2003). It is crucial for students to understand that scientific knowledge is not absolute, but it is instead based on mental models that have intrinsic limitations to their applicability.

The newly established connections made in the course between science and the visual arts intrigue my liberal arts students. They start seeing science differently—through tools of the philosophic imagination (Egan, 2005, p. 231)—as part of a complex web that links aspects of art and philosophy to the political and economic realities of a given historical period. This new framework validates for them the need for a science course in the program. Now they think that acquiring basic science literacy is paramount in our times.

Science and Art through Creative Assessments

Fostering imagination and creativity requires time and proper incentives. By employing cognitive tools, it was possible to engage students emotionally and imaginatively with the subject matter in the History of Science course. Exposing them to imaginative works in multiple forms facilitates the development of strong emotional connections with the topic. For example, Steve Martin's (1996) play *Picasso at the Lapin Agile* uses humor to portray a fictitious encounter between Einstein and Picasso in Paris in 1904, prior to their creative breakthroughs. To understand the jokes, one needs to know the succession of events in a chronological order as well as the references to other artists and scientists and their respective historical roles and contributions to their fields. To emphasize scientific concepts through images, students played with the interactive simulations *Photoelectric Effect and Models for the Hydrogen Atom* created by the University of Colorado, Boulder, and made available through their website (https://phet.colorado.edu). Playing with the simulations activates their brains to think in terms of pictures and images rather than only with the words and numbers that are the focus of traditional approaches.

As part of a partnership between Vanier College and the Department of Creative Arts Therapies from Concordia University, fine arts students from Concordia conduct two art-lab assignments during the semester. In these labs, learners create visual representations that they associate with the idea of uncertainty and the clash between Classical Newtonian cosmology and the counterintuitive nature of quantum mechanics. This activity aims to engage them with the subject through artmaking, to promote playfulness, to explore a variety of techniques, materials, colors, and textures, to reinforce the idea that the process is more important than the product, and to reassure them that they will not be judged or assessed as art students.

All these activities prepare students for the major assignment of the course: the creation of visual representations that portray multiple scientific ideas as well as a rationale for its process of creation that links to the course content. The goal is to portray these concepts using visual arts as means of creating meaning through symbolic visual representations (Eilam & Gilbert, 2014) while developing new perceptions of visual forms (Hickman & Eglinton, 2015). This instructional strategy is based on the principles of *constructionism* that shares *constructivism's* connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds "the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe" (Papert & Harel, 1991, p. 1).

Over the course of six weeks, each student creates a draft using an online document outside the classroom and participates in asynchronous dialogues through which he or she develops ideas and receives feedback from the science teacher as well as the fine arts students from Concordia. Students present their finished artwork to their classmates, write a self-reflective journal, and conduct a self-evaluation based on a rubric that is provided. This endeavor nurtures their personal and academic growth through questioning, play, and self-reflection. Students have the final word on the themes they choose and the artistic choices they make. This freedom reinforces a sense of ownership and the value of actively constructing knowledge by connecting the artwork with their own lives, passions, and interests. Based on such a personal outlook, this activity has the potential to cognitively engage students at higher levels of abstraction by enhancing their engagement and their ability to transfer knowledge across disciplines in school, as well as from school to both home and the workplace.

This longer-term, iterative creative project requires both imagination and the ability to integrate concepts. The students' creative process is as important as the final product. When compared to traditional instructional strategies—the pervasive lecture/drill/practice—used in science courses, this activity embodies a remarkable shift in philosophy of teaching, curriculum design, and pedagogy. Learners are asked to assume a more active role in their learning process by constructing meaning through an activity that challenges the common misconception that scientific knowledge is fixed and universal. As a result, their creativity and imagination are stimulated and rewarded on a personal level. Learning occurs through a process of discovery that is mediated by social interactions between peers and teachers in a stimulating environment.

The Art & Science Project started in 2009 with a liberal arts cohort. The immediate success of such a novel educational strategy at the college level gave incentive to adapt it for use in pre-university chemistry courses that are part of the Science program. It is based on a cross-disciplinary integration between the visual arts and the natural sciences to promote a deeper understanding of the role of models in the natural sciences. Since 2010, students in General, Solution, and Organic Chemistry courses create a draft of an artwork that portrays some of the central concepts and ideas in chemistry (Lima, 2016). This high-level cognitive activity can trigger the necessary reflection needed to understand threshold concepts in chemistry such as the relationship between molecular structure and reactivity. This pedagogical approach has been presented at international conferences (Lima, 2012; Lima, 2014; Lima & Wiebe, 2014) and has caught the attention of university research groups in both Canada and Germany. Recently, the project has expanded in a multi-disciplinary fashion through the exploration of core concepts in chemistry and physics using art.

The inclusion of artistic expression in the science curriculum at all levels of instruction has value, since images can engage students in ways that words and formulas cannot. As outlined by Lobman (2010), "the most valuable learning occurs when people are engaged creatively—in activities that allow them to use their imaginations intellectually, socially, artistically, and culturally" (p. 199). Meaningful learning experiences can be created by exploring students' flexibility of thought through multidisciplinary projects that require reflection over long periods while developing tolerance for ambiguity and encouraging risk taking (Eisner, 2002). At a time when scientists must be more creative than ever before, the education system must transform itself into one that cultivates innovative students. The success of this approach has the potential to boost student interest in science as well as increase the number of students pursuing science careers.

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