Chapter 3
Creating a STEAM Map: A Content Analysis of Visual Art Practices in STEAM Education

Christine Liao

STEAM Is Hot

STEAM is related to the STEM movement in education, itself a much-discussed topic in the pre-K-12, college, and community education contexts in the past few years. From policy makers to administrators, educators, and the media (e.g., Bertram, 2014; Jolly, 2014; Krigman, 2014; Pomeroy, 2012), the term STEM is used in educational contexts to refer to educational approaches and practices designed to encourage students to participate in STEM fields. Adding the arts to the STEM acronym, according to some advocators, emphasize the need for educating students to become innovators capable of competing in the global economy (Eger, 2013; Maeda, 2012). Professionals in the field of art education likewise have a stake in contributing to outcomes of educating creative and innovative students. It is, therefore, important that art educators understand what the term STEAM means in the context of their curricula.

The National Art Education Association (NAEA) sets out a position statement on STEAM education in April 2014, which defines the STEAM approach as "the infusion of art and design principles, concepts, and techniques into STEM instruction and learning" (National Art Education Association, 2014). This definition indicates that STEAM refers to the integration of any art and design learning into STEM; yet, instead of seeing STEAM as more than an instructional approach, this definition refers only to STEM instruction with/through art. The position statement also emphasizes collaboration among educators from different fields. In addition, it provided a resource detailing five other definitions of STEAM,[1] thereby indicating the organization's recognition of the term's complexity. The position statement is a

[1] See http://www.arteducators.org/research/STEAM_Definitions_Document.pdf

C. Liao (✉)
University of North Carolina Wilmington, Wilmington, NC, USA

M. S. Khine, S. Areepattamannil (eds.), *STEAM Education*,
https://doi.org/10.1007/978-3-030-04003-1_3

good start regarding helping art educators understand STEAM teaching, but other tools that can provide a range of perspectives on STEAM education are also needed.

My purpose for researching STEAM practices is to provide ways for art educators both to see their STEAM practices/curriculum in perspective and to think beyond the limitations of STEAM. I began my inquiry with these questions: What do current STEAM education practices look like? What are the goals of these practices? And, how do these practices relate to each other and the spectrum of art education and STEM Education fields?

I will start by discussing what STEAM education is and by reviewing a range of approaches to it to provide a foundation based on which educators can make their own inquiries into and create their own practices about STEAM. Based on my analysis of existing discussions focused on STEAM curricula and projects/lessons, I created the STEAM map presented in the current study to locate projects in relation to their emphasis on specific elements and goals. The STEAM map can be seen as visualized data of published current STEAM practices. Although the map does not include all STEAM curriculum practices and certainly does not extend to all the related possibilities in this area, it locates the preponderance of the practices in use and offers pathways for imagining new horizons. Overall, the map provides ways for educators to capitalize on STEAM practices, to reflect on the limitations of these, and to imagine and implement new approaches.

STEAM Curriculum Approaches

Despite the fact that STEM education has been around since the 1990s (Sanders, 2008), the usage of the term STEM is vague (Angier, 2010). A discussion of STEM in this regard is beyond the scope of this article; nonetheless, in education, STEM is considered as education in the field of science, technology, engineering, and math. However, approaches to teach students in learning these subjects and pursuing a career in these areas vary. Subsequently, adding the arts to STEM makes the usage of the term STEAM also vague. STEAM is generally understood to be a curriculum approach based on the STEM curriculum, i.e., science, technology, engineering, and math as the core subjects but with the arts (A) integrated either to the core subjects or to cultivate students' creativity and lead to innovation in STEM fields. The A includes helping students' learning of not only the visual arts but also the performing arts including music, drama/theater, and dance; and some researchers (e.g., Lewis, 2015) also advocate the inclusion of liberal arts subjects. In this article, I highlight only the integration of visual arts and design in order to focus on the implementation of STEAM in the field of art education. However, this does not mean that the other arts areas are excluded from my operational definition of the term.

Stroksdieck (2011) contends that there are two prevailing arguments in support of implementing STEAM education. According to one argument, art provides ways of seeing and knowing that differ from those captured by STEM and is, therefore, a valuable tool for apprehending STEM subjects. Stroksdieck provides data visualization as an example for this argument. Given that art can help learners to develop an understanding of scientific concepts (Dhanapal, Kanapathy, & Mastan, 2014), visualization is seen as a way to connect art and science such that it could constitute a STEAM practice in art education (Knochel, 2013). Knochel argues that art education can contribute to the understanding and discussion of how image manipulations of science data represent the "truth."

The other argument focuses on teaching art as a way to cultivate creative people (Stroksdieck, 2011). According to Trilling and Fadel (2009), even though STEM skills are in demand because they are considered necessary for careers in the twenty-first century, creativity will eventually be seen as even more important. Therefore, Trilling and Fadel proposed integrating the arts into STEM to create a STEAM focus as a central goal for twenty-first-century education. In accord with this argument, STEAM is seen as beneficial to students and to economic growth (Hanushek, Jamison, Jamison, & Woessmann, 2008). For example, John Maeda, a former president of the Rhode Island School of Design, is championing the notion of changing STEM to STEAM from exactly this viewpoint (Maeda, 2012, 2013; "STEM to STEAM," n.d.). Maeda views STEAM from the perspective of art and design education, arguing that an emphasis on STEM alone is not enough for the needs of twenty-first-century innovation. He advocates for art and science subjects to be taught together. For Maeda, the A in STEAM stands principally for visual art and design. In this view, the purpose of STEAM is to educate people to use the skills and creativity cultivated in art and design along with STEM knowledge in order to innovate and contribute to the progress of society. STEM is, therefore, of fundamental importance to social progress and economic growth, and art is the key to the innovation necessary for this kind of advancement ("STEM to STEAM" n.d.; White, 2010).

Design Education-Based STEAM Approach

Maeda's (2013) idea of emphasizing the development of design skills and creativity in an effort to create innovators is well received by art and design educators. Advocates for art and design education generally see STEAM as a way to highlight the importance of design education (Bequette & Bequette, 2012; Watson, 2015). Design education, argued Vande Zande (2010), would broaden the aims of art education and connect the economic goal that is not often present in the fine arts. Therefore, design can act as the bridge between STEM and the arts. This approach situates design education as a fundamental kind of STEAM education.

Design Thinking, typically understood as a creative problem-solving process, is often the method used to approach STEAM from the perspective of design education (Bequette & Bequette, 2012; Bush, Cox, & Cook, 2016; Gross & Gross, 2016). Researching what design thinking is and how it is taught, Donar (2011) found that "more integrated, cross–disciplinary, and holistic approach" (p. 98) is the trend of design thinking in education. Along with positioning design thinking as interdisciplinary (Cross, 2011), this inter/cross-disciplinary nature of design thinking process creates the connection between design and STEM. This perspective recognizes the complexity of the design thinking process and its potential to teach students to become critical thinkers equip with twenty-first-century skills needed across disciplines and careers (Watson, 2015).

Collaborative Approach to STEAM

For art and design educators, STEAM is not only about teaching design skills to advance STEM, but it should also be a collaborative effort between educators from various disciplines (Watson, 2016). Art and design educators, therefore, should communicate with others in STEM fields in order to determine how art can fit into the STEM/STEAM curriculum (Bequette & Bequette, 2012), and art teachers and STEM teachers should learn from each other (Wynn & Harris, 2012). This view constitutes the interdisciplinary and collaborative approach to STEAM. The concept is extended to taking the communication between art and STEM educators into a transdisciplinary space (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014). It is important to note that transdisciplinary is different from interdisciplinary. Nicolescu (1997) defines the goal of transdisciplinary (research) as "the understanding of the present world, which cannot be accomplished in the framework of disciplinary research" (para. 8). In other words, it is a space beyond (multi)disciplines. Guyotte et al. (2014) argue that a STEAM curriculum in the context of a transdisciplinary space can become a form of social practice. They also propose that working in a transdisciplinary STEAM space can help students develop creativity collaboratively (Guyotte, Sochacka, Costantino, Kellam, & Walther, 2015). At the heart of this position on STEAM is the practice of collaboration.

Collaboration in STEAM usually means that teachers/students from different disciplines work together. However, individual disciplines taught as discrete areas of focus still constitute the foundation of this approach. In other words, collaboration is based on the idea of benefiting from each other's differences. On a similar path, Yakman (2008, 2012) proposes the term STEAM written as ST∑@M[2] from an integrated curriculum perspective. In her account, an integrated curriculum can break the discipline-based limitations of most established educational approaches. ST∑@M constitutes a curriculum framework that Yakman created to structure traditional academic subjects to be taught in an integrated curriculum (2008). She defines STEAM as "Science and Technology, interpreted through Engineering and the Arts, all based in a language of Mathematics" (2008, p. 21). In this view, the A in STEAM stands for all the arts as well as for the humanities and social sciences. This perspective focuses on a holistic approach to the curriculum (Yakman & Lee,

[2] The symbol ∑ (sigma), used in math to refer to the sum of all values, is used here to emphasize the STEM connection.

2012), such that Yakman advocates for the importance of all the subjects and, therefore, that students should gain a background in all of them. However, in this framework—referred to as the STEAM Pyramid[3]—the subjects are not of equal importance: The arts, humanities, and social sciences comprise only one-fifth of an integrated curriculum that remains focused on STEM subjects. Yakman advocates integrating different subjects through a common theme or project, and each individual subjects in this STEAM curriculum can be taught by different teachers to reduce the burden of teachers (Joe, 2017). In addition to that this approach still advocates a divide of individual subjects, this approach has evolved into a curriculum system that is taught to teachers through their specific professional development partnership and membership. Thus, the practice of this idea is not transparent to people who do not have access to their professional development and curriculum. It is unclear that how this idea is actually practiced in the day-to-day school curriculum.

Approaching STEAM Through Arts Integration

Perhaps, the practical approach to STEAM education is through arts integration. Advocates of arts integration are increasingly using the term STEAM as a vehicle for disseminating practices associated with arts integration. Unlike Yakman's integrated STEAM curriculum framework, arts integration is often discussed at the level of instructional approach and lessons, although its larger goal is also "integration," which can be implemented in a variety of ways. As such, much as there are many definitions of arts integration, a general understanding is that the term refers to the teaching of other subjects through the arts (Goldberg, 2011). Different terms such as arts infusion (McDonald, 2010) or arts-based teaching and learning (Marshall, 2014) are used to refer to arts integration. The Kennedy Center's definition of arts integration, as set out by Silverstein and Layne, focuses on the potential of using the arts to create the understanding of both the art subject and the subject(s) with which it is connected in a given curriculum:

> Arts integration is an approach to teaching in which students construct and demonstrate understanding through an arts form. Students engage in a creative process which connects an art form and another subject area and meets evolving objectives in both. (Silverstein & Layne, 2010)

Marshall (2014) discusses that Silverstein and Layne's definition of arts integration is multi-model arts-based learning, and this definition has gone beyond many other views that the arts production is only a strategy for teaching and learning other subjects. To further conceptualize arts integration, Marshall argues that arts integration is a transdisciplinary field and its pedagogy goes beyond disciplinary boundaries.

[3] The STEAM Pyramid can be found here: https://steamedu.com/pyramidhistory/

Viewed through the lens of arts integration, STEAM can be seen as a teaching approach focused on the benefits of integrated learning. However, no matter based on which perspective or definition of arts integration, embedding the A in STEM makes obvious that the purpose of STEAM is to integrate the arts into the teaching of STEM subjects and/or to teach STEM subjects through the arts. Even, as described in the Kennedy Center's definition, art integration should focus on fulfilling objectives for both the arts and another subject(s), emphasizing STEM subjects often results in the arts serve as knowledge delivering tool. In practice, the arts are often diluted in arts integration practices in the general classroom such that the focus is only the "main" subject(s) (LaJevic, 2013). Further, in Riley's (2013) view, "too often, the arts are used as enhancement in the lesson (think 'shadow boxes') rather than as a true means of connecting and communicating understanding" (para. 8). The mistreatment of the arts in art integration practice is also brought into the STEAM curriculum. Art is often reduced to only the aesthetics of a project. For example, in a fourth-grade STEAM project teaching students to create a prosthetic, the art learning in this project is described as "aesthetics of designing a prosthetic" (Bush et al., 2016, p. 111).

Although advocates argue that significant benefits can accrue from integrating the arts into STEM learning, as described by Catchen and DeCristofano (2015), many in STEM fields think of the arts as lacking rigor. Such a view of the arts on the part of STEM practitioners may have resulted in an apparent reluctance to use the term STEAM and a tendency to criticize this concept for drawing attention away from STEM (Dunning, 2013; May, 2015). Even though art educators know that students develop critical thinking and creative problem-solving skills through the arts (e.g., Eisner, 2002), misconceptions of the arts hinder efforts to bridge the gaps between those in STEM and those in non-STEM fields.

The NAEA's position statement falls within the view of STEAM associated with arts integration practices. However, educators should be cautious in regard to discussing STEAM solely through the lens of arts integration because the arts could come to be seen not as a subject area in its own right but merely as a tool for learning STEM. Even though advocates in this camp emphasize the importance of the arts, they are clearly a vehicle for teaching STEM subjects—not the other way around. Equating arts integration with STEAM or using the term STEAM to attract attention to arts integration could also result in a loss of the idea that all subjects should be treated as equal within the purview of arts integration.

Approaching STEAM Through Project-Based Learning and the Maker Movement

Whether STEAM is approached with an emphasis on collaboration or on integration, project-based learning (PBL), which is rooted in John Dewey's philosophy of learning by doing (Boss, 2011), is one of the most popular STEM/STEAM-teaching approaches (Markham, 2012; Miller, 2014). According to Thomas (2000), project-based learning "involve[s] students in design, problem-solving, decision making, or investigative activities; give[s] students the opportunity to work relatively autonomously over extended periods of time; and culminate[s] in realistic products or presentations" (p. 1). PBL is also advocated by Yakman (2008) and by Bequette and Bequette (2012). Through processes associated with PBL, students can engage in learning and using STEAM knowledge and skills, and there is clear potential for art and STEM to be treated as equally important to the success of any given project.

In emphasizing learning through "doing/making" projects, however, many STEM/STEAM curricula confuse PBL with project-oriented learning (Larmer & Mergendoller, 2010; Robin, 2011). Project-based learning focuses on the problem-solving process, but project-oriented learning focuses on the finished product, which is often a craft item or school-style art (Gude, 2013). Although proponents for the arts emphasize "making" as an essential art skill, often very little, if any, art knowledge is taught in the process of creating these "projects." In an approach of this nature, hands-on making is the only way in which art is taught in STEAM. Consequently, art is not considered beyond its function as a tool/medium for STEM, or worse, its function is entirely decorative.

In another trend related to the rise of STEM and STEAM education, the maker movement also considers hands-on and making-centered approach (Dougherty, 2012), especially with digital media, electronic technology, and robotic technology. This movement has gained popularity among the general public and also made an impact on education (Halverson & Sheridan, 2014). In fact, some educators see the maker movement as an opportunity for STEM/STEAM education (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Gerstein, 2013; Peppler & Bender, 2013). Interest in connecting the maker movement with STEAM education is often associated with the project-orientated and hands-on learning approach described above, but not necessary with PBL. As art is generally seen as a hands-on subject, art educators are also embracing the maker movement (Ciampaglia & Richardson, 2014). The critical pedagogy approach practiced by Ciampaglia (2014) is an important direction to consider STEAM education through maker movement.

However, this movement is often criticized for its white male-dominated culture (Grenzfurthner & Schneider, n.d.). Further, although art skills and creativity are valued, most of the creative "projects" are function-driven and, again, geared toward socially constructed male interests, such as electronics or robots (Buechley, 2013). Conceptual expression and cultural connections are rarely seen in this kind of projects. It is, therefore, important to identify what art can bring to the maker movement and to distinguish maker projects, such as assembling a robot, from more creative uses of such technology to express ideas. Some art educators' advocates for critical making (Patton & Knochel, 2017) aim at bringing maker movement to the next level. Similarly, Ciampaglia and Richardson (2014) emphasized using critical pedagogy to teach digital making. These examples are ways to consider a STEAM education beyond only creating high-tech craft.

Summary: Many Shades of STEAM

These different viewpoints on what constitutes STEAM education do not have clear boundaries. There is no single definition of STEAM or by extension of what constitutes STEAM practices. Instead, there is a broad spectrum of practices in the field of art education and arts integration all claiming the term STEAM.

Some practices referred to as STEAM focus exclusively on only one STEM subject in concert with one or more arts subjects. These can be seen as one piece of a STEAM curriculum, for example, creating digital media as a way of integrating technology literacy and art (Blair, 2015). As technology is one of the focal STEM subjects, a curriculum integrating digital technology/media creation would constitute a de facto STEM curriculum. The matter of whether any given curriculum of this kind is a STEAM curriculum depends on how art making is defined.

Other examples of STEAM education range from art projects with science as the central topic (e.g., Gibbons, 2015; Hare & Feierabend, 2015) to art projects with the focus on design (e.g., Giordano, 2015) and from lessons integrating art and math (e.g., Ward & Albritton, 2015) to lessons in which collaborative projects cross-disciplinary boundaries (e.g., Barnett & Smith, 2013) and to a focus on artists' creative explorations of STEM topics (e.g., Joksimovic-Ginn, 2014). Each of these practices has its own role and function at different levels of education.

In addition, artists' STEAM practices create another territory of STEAM practice for art educators to explore. Examples of STEAM practices in art can be seen in "Steam," a 2014 exhibition curated by Patricia Miranda at the ArtsWestchester's Arts Exchange. The exhibition included pieces showing the involvement of artists in scientific disciplines (Hodara, 2014). For example, artist Carl Van Brunt uses a fractal generator to create images of "mathematical nature." Another artist, William Meyer, created a transparent backpack with a "complex system of earth microorganisms, chemistry and botany" (Hodara, 2014, para. 7). In fact, artists have long worked with STEM knowledge, concepts, ideas, and technologies. Leonardo da Vinci would be a famous example. How artists' practices can be translated into art teaching and STEAM education is an important question for art educators.

Whatever the viewpoint and whatever the practices associated with STEAM, the question arises as to its value for contemporary society. Although STEM knowledge and skills are essential for success in the twenty-first century and the combination of art and STEM holds promise for improving the quality of life, STEM and STEAM are not the panacea. As some critics point out, a greater focus on STEM subjects means that there is less time for other areas, such as the humanities (Ossola, 2014; Zakaria, 2015). STEAM, however, can fill in some of the missing pieces for STEM education. But more importantly, educators need to see the bigger picture in regard to STEAM education practices to address the issues. Therefore, in order to see what current STEAM education practices look like, I created a snapshot of current practices and presented it as the STEAM map in the next section.

Creating a STEAM Map

Method

The focus of this study is to understand what the STEAM curriculum in art education and the integration of visual arts with STEM look like in practice. The result of the visualized data is presented as a STEAM map showing the distributions of different emphasizes of STEAM curricula. I conducted content analysis using magazine articles, lessons published online, and journal articles published from 2012 to 2016 in the field of art education and STEAM (Table 3.1) aims for practitioners to see the trends and approaches to STEAM curriculum. The data collection of this study focused solely on visual arts-related STEAM curricula, projects, lessons, and artwork. These published projects serve as examples for those interested in STEAM education.

Content analysis is traditionally used as a quantitative research method, but with the development of qualitative content analysis, it has become a method to bridge quantitative and qualitative research approaches (Duriau, Reger, & Pfarrer, 2007; Hsieh & Shannon, 2005; Mayring, 2000). In this research, my approach to content analysis is mixed method. I use qualitative content analysis, "a research method for the subjective interpretation of the content of text data through the systematic

Table 3.1 Sources of Data

Publication/online community	Description	Number of Projects Selected (2012–2016)
School Arts	This is a practitioner magazine in art education	12
Arts and Activities	This is a practitioner magazine in art education	1
Art Education	This is a practitioner journal in art education	8
EducationCloset	Although EducationCloset (http://educationcloset.com/steam/lessons/) is not a publication, it is a popular arts integration and STEAM online community that includes lesson plans	6
STEAMed Magazine	This is a practitioner magazine focused specifically on STEAM	13[a]
The STEAM Journal	This is a STEAM-focused journal that has multiple sections including Articles, Artwork, Field Notes, and Reflections	15
		Total: 55

[a]Due to the access issue, only the articles published in 2015 in the *STEAMed Magazine* are collected. The magazine's inauguration issue is January 2015

classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005, p. 1278), and specifically using the inductive category development method (Mayring, 2000) to create category and analysis the text. The texts are interpreted based on the different goals and focus of various STEAM education approaches discussed earlier. I also borrow from the counting method of quantitative content analysis to present the trend of STEAM and create the STEAM map.

I only collected data on projects that use either the term STEAM or STEM in conjunction with art. The projects included range from early childhood to college to community contexts. In addition, even though some of the projects focused on only one STEM subject, they were included providing either the term STEAM or STEM and art was used. Some of the articles selected did not specifically focus on discussing a STEAM project but were selected if one or more STEAM practices were briefly mentioned as an illustration of the author's idea of STEAM curriculum. On the other hand, some articles, even though focusing on discussing STEAM, were not selected, if no specific STEAM art-making curriculum project was included. In regard to the data collected, discussions of school-wide STEAM curricula that did not mention a specific project were not included. All the STEAM projects from which data were collected met the following criteria:

1. Included the visual arts
2. Used the term STEAM or STEM and art or were published in a STEAM-focused publication
3. Involved creative production (creating an artwork or a STEM application), including through participatory art

Although the current study does not present a comprehensive survey, the publications and the website included are representative places in which STEAM curricula are published and can be easily accessed by practitioners, and these are places advocate for STEAM practices in art education and other disciplinary areas.

Fifty-five STEAM projects involving the visual arts are included in my analysis. These projects are analyzed using categories created through qualitative content analysis inductive development method. This method allows me to create categories through a series of steps starting from determining the categories and adjusting the categories base on the materials read. I started with listing possible categories based on the main approaches to STEAM practice in the projects. Several categories were created in order to determine the different objectives/approaches distinguishing the various projects. After setting up the initial categories, the data texts are carefully read and interpreted, and some categories are divided into smaller categories or combined into one category. After reading most of the materials, the categories are adjusted again. The final analysis is based on the categories that have been revised a few times (Mayring, 2000). Some of the projects selected utilize multiple approaches. I categorize these projects only based on the main approach and goal.

After creating the categories (Table 3.2), the data are further analyzed based on the following dimensions: art, STEM, creative expression/application, and knowledge/skills. The dimensions are created based on the traditional disciplinary concept separating art and STEM and the learning objectives from revised Bloom's

Table 3.2 Categories

A	Creating art informed by STEM or art (concept) based on STEM knowledge
B	Using STEM knowledge to create art (STEM knowledge is a tool to achieve art-making goals)
B-1	Creating art while also acquiring STEM knowledge driving by the art/medium and process
B-2	Creating art with STEM knowledge to educate/advocate STEM-related or other issues
C	Creating art and representing researched/learned STEM knowledge in creative ways
C-2	Learning design process (Design Thinking) as a way to learn STEAM skill/knowledge
E	Using art and design skills and STEM knowledge to create STEM applications (projects)
F	Creating real-world application-oriented projects while learning both art and STEM content
G	Creating art to learn, understand, and represent/demonstrate STEM content
G-1	Using art techniques and exploring art medium to learn STEM skills/knowledge/content
G-2	Using art to illustrate STEM content/data visualization
H	Learning a skill/concept that is shared knowledge/skill between art and STEM
I	Engaging in hands-on activities to create a STEM/STEAM project (in makerspace setting)
Y	Collaborating with people in STEM to create art to highlight/solve STEM issues
Z-1	Collaborating with (teaching) artists to create art that integrates with STEM content/knowledge or collaborating in an interdisciplinary way to create art while learning both STEM and art
Z-2	Exploring a topic/theme/concept through interdisciplinary learning or collaboration
Z-3	Solving a problem through transdisciplinary collaboration

taxonomy (Anderson & Krathwohl, 2001). The art or STEM dimensions are based on the project's focal discipline. The creative expression/application and knowledge/skill learning dimensions are based on the main learning objective of the project. Although most of the projects have goals relating to both art and STEM, many give considerably more weight to one or the other of these. The categories are located on the map based on the four dimensions outlined.

Drawing the Map

In order to visualize the distribution of the STEAM practices, I created a map using a coordinate system that can represent the data in two-dimensional space. Using the quantitative method of counting, the STEAM map shows the number of STEAM projects found in the collected data and the location of the categories. The location of each category was determined by its relativeness to the different dimensions. The center area is where different dimensions meet. It indicates the integration and balance of different dimensions. Therefore, the center is circled and identified as an inter/transdisciplinary collaboration area. In order to verify that the locations of the categories are correctly represented on the map, the categories were grouped based

Table 3.3 STEAM Approaches and Categories

STEAM approaches	Categories
Shared knowledge	H
Design-based STEAM education	C-2
Collaboration, inter/transdisciplinary	Y, Z-1, Z-2, Z-3
Arts integration approach	B-1, C, G, G-1
Project-based learning	B-2, E, F
Maker movement-based approach	I
Artist and art education focused	A, B

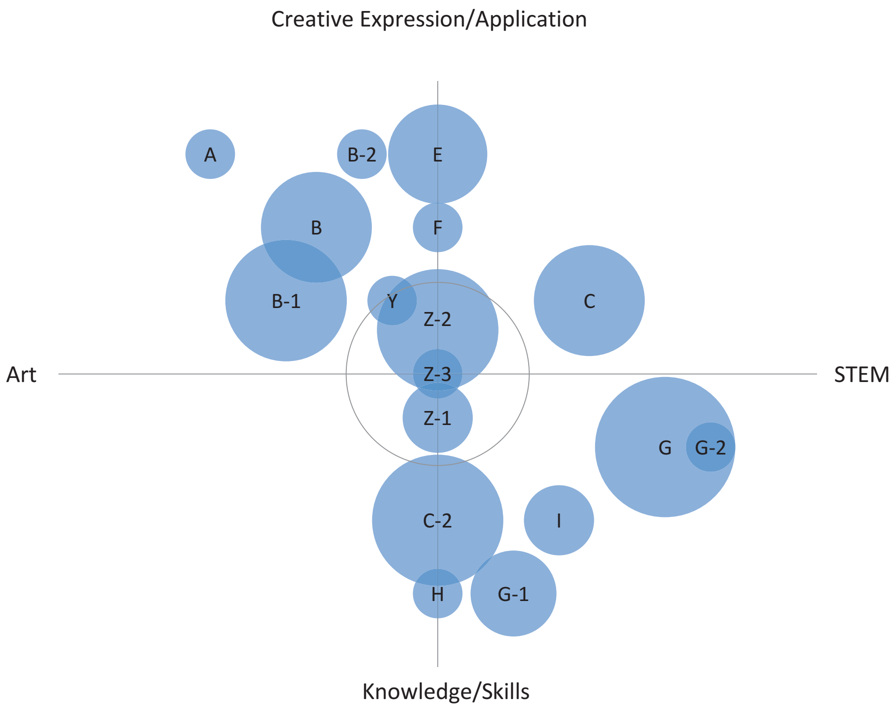

Fig. 3.1 STEAM Map

on the approaches discussed earlier (Table 3.3), which include focuses on shared knowledge, design education or design thinking approach, arts integration approach, collaboration and inter/transdisciplinary approach, project-based learning, maker movement-based approach, and artists and art-making focused approach. The groups allowed me to see that most categories within the same STEAM approach are located close to each other, with the exception of arts integration approach. This is due to the complex nature of this approach. The visualized data was created using the Excel program. The number of projects in each category is indicated by a circle of a corresponding size: The more projects in a category, the bigger the circle used to represent that category. In Table 3.2, a complete list of the categories is presented. These are the keys for reading the STEAM map (Fig. 3.1).

Stories the Map Tells

The map is by no means comprehensive and is limited in some ways. However, it does provide a way to visualize the different approaches and objectives between current STEAM education practices. As I collected only data about visual arts, this study does not represent other arts areas that are included in STEAM. The projects collected ranged widely from single STEAM lessons/projects to collaborations across disciplines and beyond schools to community education.

The inter- or transdisciplinary collaborative approaches are located in the middle of the map (represented by Y, Z-1, Z-2, and Z-3) because these projects are not situated specifically in the context of either the visual arts or of a STEM subject and are not focused on merely learning a basic knowledge/skill or creative conceptual expression. That is, inter- or transdisciplinary collaborative approaches usually bring both learning/applying knowledge and creative expression together to achieve a goal, such as solving a problem. For example, the *EcoScience + Art* initiative led by Changwoo Ahn (2015) is a collaborative STEAM initiative that is continuing to evolve. One project in this initiative, *The Rain Project*, was designed to "promote participation and collaboration in the context of ecological literacy and campus sustainability" (Ahn, 2015, p. 4). Students from various disciplines worked together to build a floating wetland over the period of a year in order to address stormwater issues and improve the quality of the water at their campus. This project is an interdisciplinary collaboration that led to real-world problem solving.

A general trend captured by the STEAM map is represented by the categories with the larger circles (G, B-1, C-2). These locations are away from the center of the map, indicating that many of the practices in these contexts are still situated in specific disciplines. Further, more than half of the projects in these categories focus more on learning the basic art or STEM knowledge/skills than on creative applications.

The map shows that two kinds of STEAM practices currently dominate the discourse in the field of art education: practices that proceed from the idea of using STEM knowledge to create art represented by the B, B-1, and B-2 categories, and practices that proceed from the idea of creating art to learn, understand, represent, or demonstrate STEM content, represented by the G category (the largest circle on the map). The G and B-1 categories belong to arts integration approach, which uses art creation as a way to learn STEM content. The difference between these two categories is that projects in G category use art making as a way to understand STEM content or demonstrate learning. The goal is STEM content learning, and art is the vehicle to achieve the goal. While the projects in B-1 category focus on art making but use the opportunity to also learn about STEM content related to the art medium or making process. The goal of these projects is art learning oriented. The G category is strongly corresponding with the goal of arts integration set out by Kennedy Center, which is to understand and demonstrate learning of other subjects through art making. The larger number of projects in this category indicated that in the field of art education, arts integration is a popular approach to teaching STEAM. The C category is similar to G category, but the difference is that C category use art to represent learning in STEM area, but the art making and the STEM learning are likely separated. While the STEM learning in G category is through the art making, so the learning is integrated. In addition, the C-2 category is another popular STEAM practice. It represents the design education-based approach to STEAM education. The projects in this category teach students to use design thinking process to design their project and learn about art and STEM together.

Many projects are situated in the categories located along the X axis, which is in the middle of art and STEM. This means that these projects view art and STEM equally and combine both areas to reach the maximum benefit. It is interesting to note that there is no category locates at the lower left section, which indicates learning basic art skills. This might be due to the limitation of selected data. In addition, the center area with categories Z-1, Z-2, and Z-3 is showing strong numbers of advocates and projects. This is also a good indication that the collaborative approach is practical, and many educators see the value of this approach.

Beyond the Map

The map shows only the approaches taken in the projects collected. Therefore, there are unmapped territories. The STEAM curriculum projects collected in this study are the ones that have been published and publicly available. Thus, some popular curriculum practices, such as those developed in Yakman's STEAM Education professional development program are not included. In addition, the map does not show school-wide STEAM curriculum reform. It would be a worthwhile endeavor to consider how specific STEAM-focused schools approach STEAM curricula in the future. Further, it is important to note that there are some STEAM practices, although relatively few, in the STEM field that were not included in this study because I intended to focus on how the art fields (art education and arts integration) practices STEAM education. Despite its limitations, however, the map provides a useful tool based on which art educators can locate their STEAM projects in the context of current STEAM education practices. Art educators can look at the dimensions and locations of each category and decide how to adjust their STEAM curriculum/project to considering expanding the curriculum/project into more dimensions.

I would like to propose more dimensions for a future map as well. As the STEAM map shows, most of the projects center on either learning art or STEM knowledge/skills or creating an art/functional application project. A very small number of projects focus on social practices, justice, or environmental awareness (e.g., Ahn, 2015; Fontes, 2015; Guyotte et al., 2014). Aligned with Patton and Knoche'sl (2017) view of the importance of criticality of digital making in STEAM, in my view, a STEAM education that begins from and engages with a conceptual exploration of our society pertaining to issues such as social and economic justice, environmental sustainability, or human rights has the potential to be truly transformative. When there is sufficient STEAM curriculum to warrant including dimensions for these areas of concern, it will mean that steps have been taken to enrich the STEAM curriculum and prepare young children and adults to better understand and play a positive role in the society they live in as a whole.

Future Directions of STEAM Education

The idea that STEAM education has the ability to transform students' learning of STEM subjects and can provide them with important skills needed for the future success has driven the discourse on STEAM overall. Art education is in a unique position in regard to the STEAM movement because of the shared knowledge between art and STEM subjects in many respects, such as patterns in both art and math. However, it is also necessary to attend to the subject areas and discourses that the STEAM movement neglects. As there are many perspectives and approaches on STEAM, some worried that the importance of liberal arts education might lose in the current. Therefore some commentators are advocating for including the liberal arts under A in STEAM (e.g., Gogus, 2015; Lewis, 2015). Further, no matter STEM or STEAM movement, the perception that the STEM fields are driving social progress and that such progress is good for society should be carefully examined. STEAM education should also include education focused on our relationship with and the ethics of new technology and scientific advances. For example, although it is at the center of efforts to merge science and art, BioArt has long been considered controversial in terms of its ethics (Munster, 2005; Zylinska, 2009). From a diversity and gender equality perspective, we want to encourage girls to participate in STEM fields, but at the same time, the working conditions in these fields for women need to be improved (Fouad & Singh, 2011; Steele, 2013). In addition, some argue that including the arts in STEM will attract girls to STEM fields (Gustlin, 2014; Santana, 2015). However, doing so might bolster stereotypical ideas about girls' preferences. The maker movement, which is another strong force pushing the STEAM movement, has been criticized for its white male-centered culture (Chachra, 2015). These are all issues that need to be addressed in the context of STEAM.

In this context, the question is this: How can art teachers teach STEAM? The answer: Art making, especially involving conceptual exploration, can function well as the central approach. Art educators who advocate for STEAM consider art making to be an important component of the STEAM curriculum (Bequette & Bequette, 2012; Wynn & Harris, 2012). Although working in a transdisciplinary space is the ideal, it requires teamwork and extended planning. In reality, this would be a big step forward for many educators. Working toward the goal of establishing a transdisciplinary space, individual teachers can also start with small strategies and class projects in order to start building bridges between art and STEM.

The STEAM map should serve as a way to locate the goals and approaches of current STEAM practices and as a basis for art educators and other stakeholders to envision advancing into other areas. Although the study is limited, it shows that educators are exploring what constitutes as STEAM curriculum in the past few years through different approaches. In the flow of discussions on this subject, STEAM functions as a political term by bringing attention to the arts. I encourage more art educators to provide their perspectives in an effort to shape the directions that STEAM takes.

References

Ahn, C. (2015). EcoScience + Art initiative: Designing a new paradigm for college education, scholarship, and service. *STEAM Journal, 2*(1), Article 11. https://doi.org/10.5642/steam.20150201.11.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Angier, N. (2010, October 5). STEM education has little to do with flowers. *New York Times*. p. D2.

Barnett, H., & Smith, J. R. A. (2013). Broad vision: The art & science of looking. *The STEAM Journal, 1*(1), Article 21. https://doi.org/10.5642/steam.201301.21.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40–47.

Bertram, V. (2014). STEM or STEAM? We're missing the point. Retrieved from http://www.huffingtonpost.com/vince-bertram/stem-of-steam-were-missin_b_5031895.html

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education, 99*(1), 98–120.

Blair, J. M. (2015). BioShocked: environmental game design. *School Arts, 114*(8), 34–35.

Boss, S. (2011, September 20). Project-based learning: A short history. Retrieved from http://www.edutopia.org/project-based-learning-history

Buechley, L. (2013, October). *Thinking about making*. Presented at the FabLearn Conference, Palo Alto, CA. Retrieved from http://edstream.stanford.edu/Video/Play/883b61dd951d4d3f90abeec65eead2911d

Bush, S. B., Cox, R., & Cook, K. L. (2016). A critical focus on the M in STEAM. *Teaching Children Mathematics, 23*(2), 110–114. https://doi.org/10.5951/teacchilmath.23.2.0110

Catchen, R. D., & DeCristofano, C. (2015). What's wrong with interpretive dance? Embracing the promise of integrating the arts into STEM learning. *The STEAM Journal, 2(*1), Article 9. https://doi.org/10.5642/steam.20150201.9.

Chachra, D. (2015, January 23). Why I am not a maker. Retrieved from http://www.theatlantic.com/technology/archive/2015/01/why-i-am-not-a-maker/384767/

Ciampaglia, S. (2014). Critical pedagogy 2.0: Researching the visual culture of marketing with teenage coresearchers. *Studies in Art Education, 51*(6), 359–369.

Ciampaglia, S., & Richardson, K. (2014). *The Plug-in studio: Art education for the maker age*. Presented at the FabLearn 2014, Stanford, CA: Stanford University. Retrieved from http://fablearn.stanford.edu/2014/wp-content/uploads/fl2014_submission_6.pdf

Cross, N. (2011). *Design thinking: Understanding how designers think and work*. New York: Berg.

Dhanapal, S., Kanapathy, R., & Mastan, J. (2014). A study to understand the role of visual arts in the teaching and learning of science. *Asia-Pacific Forum on Science Learning and Teaching, 12*(2), 12.

Donar, A. (2011). Thinking design and pedagogy: An examination of five Canadian post-secondary courses in design thinking. *Canadian Review of Art Education, 38*, 84–102.

Dougherty, D. (2012). The maker movement. *Innovations, 7*(3), 11–14.

Dunning, B. (2013). *Can we be clear on something? It's STEM, not STEAM*. Retrieved from http://www.skepticblog.org/2013/03/14/stem-not-steam/

Duriau, V. J., Reger, R. K., & Pfarrer, M. D. (2007). A content analysis of the content analysis literature in organization studies: Research themes, data sources, and methodological refinements. *Organizational Research Methods, 10*(1), 5–34. https://doi.org/10.1177/1094428106289252

Eger, J. (2013). STEAM...now! *STEAM Journal, 1*(1), Article 8. https://doi.org/10.5642/steam.201301.08.

Eisner, E. W. (2002). *The arts and the creation of mind*. New Haven, CT: Yale University Press.

Fontes, K. (2015, January). Art is awesome! Creating using LEGO animation. *STEAMed*, 22–23.

Fouad, N. A., & Singh, R. (2011). *STEMMING the tide: Why women leave engineering*. Milwaukee, WI: University of Wisconsin-Milwaukee. Retrieved from http://energy.gov/sites/prod/files/NSF_Stemming%20the%20Tide%20Why%20Women%20Leave%20Engineering.pdf

Gerstein, J. (2013, July 23). *STEAM and maker education: Inclusive, engaging, self-differentiating*. Retrieved from https://usergeneratededucation.wordpress.com/2013/07/23/steam-and-maker-education-inclusive-engaging-self-differentiating/

Gibbons, E. (2015). Expressive organic forms. *School Arts, 115*(1), 29–31.

Giordano, K. (2015). The physics of sitting. *School Arts, 115*(1), 20–21.

Gogus, A. (2015). Reconceptualizing liberal education in the 21st century: The role of emerging technologies and STEAM fields in liberal education. In X. Ge, D. Ifenthaler, & J. M. Spector (Eds.), *Emerging technologies for STEAM education: Full STEAM ahead* (pp. 277–292). New York: Springer.

Goldberg, M. (2011). *Arts integration: Teaching subject matter through the arts in multicultural settings* (4th ed.). Boston: Pearson.

Grenzfurthner, J., & Schneider, F. A. (n.d.). Hacking the spaces. Retrieved from http://www.monochrom.at/hacking-the-spaces/

Gross, K., & Gross, S. (2016). Transformation: Constructivism, design thinking, and elementary STEAM. *Art Education, 69*(6), 36–43.

Gude, O. (2013). New school art styles: The project of art education. *Art Education, 66*(1), 6–15.

Gustlin, D. (2014). *Why add art to STEAM*? Retrieved from http://educationcloset.com/steam/why-add-art-to-steam/

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Kellam, N. N., & Walther, J. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. *International Journal of Education and the Arts, 16*(15), 1–38.

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Walther, J., & Kellam, N. N. (2014). STEAM as social practice: Cultivating creativity in transdisciplinary spaces. *Art Education, 67*(6), 12–19.

Halverson, E. R., & Sheridan, K. M. (2014). The maker movement in education. *Harvard Educational Review, 84*(4), 495–504.

Hanushek, E. A., Jamison, D. T., Jamison, E. A., & Woessmann, L. (2008). Education and economic growth: It's not just going to school but learning that matters. *Education Next, 8*(2), 62–70.

Hare, T., & Feierabend, J. (2015). Wondrous watercolor cell illustrations. *School Arts, 115*(1), 36–37.

Hodara, S. (2014, July 25). Putting the A in STEAM. *New York Times*. Retrieved from http://www.nytimes.com/2014/07/27/nyregion/putting-the-a-in-steam.html

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Joe, F. (2017). STEAM teaching and learning. *China Science & Technology Education, 253*, 6–7.
Joksimovic-Ginn, B. (2014). Can art stress? *The STEAM Journal, 1*(2), Article 16. https://doi.org/10.5642/steam.20140102.16.
Jolly, A. (2014, November 18). STEM vs. STEAM: Do the arts belong? *Education Week: Teacher*. Retrieved from http://www.edweek.org/tm/articles/2014/11/18/ctq-jolly-stem-vs-steam.html
Knochel, A. (2013). Histochemical seeing: Scientific visualization and art education. *Studies in Art Education, 54*(2), 187–190.
Krigman, E. (2014, February 13). *Gaining STEAM: Teaching science through art*. Retrieved from http://www.usnews.com/news/stem-solutions/articles/2014/02/13/gaining-steam-teaching-science-though-art
LaJevic, L. (2013). Arts integration: What is really happening in the elementary classroom? *Journal for Learning Through the Arts, 9*(1), 1–28.
Larmer, J., & Mergendoller, J. R. (2010). *The main course not dessert*. Novato, CA: Buck Institute for Education. Retrieved from http://bie.org/object/document/main_course_not_dessert
Lewis, A. L. (2015). Putting the "H" in STEAM: Paradigms for modern liberal arts education. In X. Ge, D. Ifenthaler, & J. M. Spector (Eds.), *Emerging technologies for STEAM education: Full STEAM ahead* (pp. 259–276). New York: Springer.
Maeda, J. (2012, October 2). STEM to STEAM: Art in K-12 is key to building a strong economy. Retrieved January 17, 2015, from http://www.edutopia.org/blog/stem-to-steam-strengthens-economy-john-maeda
Maeda, J. (2013). STEM + Art = STEAM. *The STEAM Journal*, *1*(1), Article 34. https://doi.org/10.5642/steam.201301.34.
Markham, T. (2012). *STEM, STEAM, and PBL*. Retrieved from http://edge.ascd.org/blogpost/stem-steam-and-pbl
Marshall, J. (2014). Transdisciplinarity and art integration: Toward a new understanding of art-based learning across the curriculum. *Studies in Art Education, 55*(2), 104–127.
May, G. S. (2015). *STEM, not STEAM*. Retrieved from https://www.insidehighered.com/views/2015/03/30/essay-criticizes-idea-adding-arts-push-stem-education
Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative Social Research*, *1*(2). Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/1089
McDonald, N. (2010). *Handbook for K-8 arts integration: Purposeful planning across the curriculum*. Boston: Pearson.
Miller, A. (2014). *PBL and STEAM education: A natural fit*. Retrieved from http://www.edutopia.org/blog/pbl-and-steam-natural-fit-andrew-miller
Munster, A. (2005). Why is BioArt not terrorism?: Some critical nodes in the networks of infomatice life. *Culture Machine*, *7*(0). Retrieved from http://www.culturemachine.net/index.php/cm/article/view/31
National Art Education Association. (2014, April). *Position statement on STEAM education*. National Art Education Association. Retrieved from https://www.arteducators.org/advocacy/articles/143-position-statement-on-steam-education
Nicolescu, B. (1997, November). *The transdisciplinary evolution of the university: Condition for sustainable development*. Retrieved from http://ciret-transdisciplinarity.org/bulletin/b12c8.php
Ossola, A. (2014, December 3). *Is the U.S. focusing too much on STEM?* Retrieved from http://www.theatlantic.com/education/archive/2014/12/is-the-us-focusing-too-much-on-stem/383353/
Patton, R., & Knochel, A. (2017). Meaningful makers: Stuff, sharing, and connection in STEAM curriculum. *Art Education, 70*(1), 36–43.
Peppler, K. A., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *The Phi Delta Kappan, 95*(3), 22–27.
Pomeroy, S. R. (2012, August 22). *From STEM to STEAM: Science and art go hand-in-hand*. Retrieved from http://blogs.scientificamerican.com/guest-blog/from-stem-to-steam-science-and-the-arts-go-hand-in-hand/

Riley, S. (2013, December 18). *Pivot point: At the crossroads of STEM, STEAM and arts integration*. Retrieved from http://www.edutopia.org/blog/pivot-point-stem-steam-arts-integration-susan-riley

Robin, J. (2011). *What project based learning isn't*. Retrieved from http://howtovideos.hightech-high.org/video/265/What+Project+Based+Learning+Isn't

Sanders, M. E. (2008). STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4), 20–26.

Santana, M. (2015). *Dresses' flashing lights aim to attract girls to STEM*. Retrieved from http://www.sun-sentinel.com/features/south-florida-parenting/stages/child/sfp-dresses-flashing-lights-aim-to-attract-girls-to-stem-20150302-story.html

Silverstein, L. B., & Layne, S. (2010). *What is arts integration?* Retrieved from http://artsedge.kennedy-center.org/educators/how-to/arts-integration/what-is-arts-integration

Steele, B. (2013). *Something about STEM drives women out*. Retrieved from http://www.news.cornell.edu/stories/2013/11/something-about-stem-drives-women-out.

STEM to STEAM. (n.d.). Retrieved from http://stemtosteam.org/about/

Stroksdieck, M. (2011). *STEM or STEAM?* Retrieved from http://scienceblogs.com/art_of_science_learning/2011/04/01/stem-or-steam/

Thomas, J. W. (2000). *A review of the research on project-based learning*. San Rafael, CA: Autodesk Foundation. Retrieved from http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. San Francisco: Jossey-Bass.

Vande Zande, R. (2010). Teaching design education for cultural, pedagogical, and economic aims. *Studies in Art Education, 53*(1), 248–261.

Ward, R. A., & Albritton, J. (2015, October). Math meets cubism. *STEAMed*, 23–27.

Watson, A. D. (2015). Design thinking for life. *Art Education, 68*(3), 12–18.

Watson, A. D. (2016). Revving up the STEAM engine. *Art Education, 69*(4), 8–9.

White, H. (2010, November). *STEAM – Not STEM whitepaper*. Retrieved from http://steam-not-stem.com/articles/whitepaper/

Wynn, T., & Harris, J. (2012). Toward a STEM + arts curriculum: Creating the teacher team. *Art Education, 65*(5), 42–47.

Yakman, G. (2008). ST∑@M education: An overview of creating a model of integrative education. In *Research on technology, innovation, design and engineering (TIDE) teaching* (pp. 335–358). Salt Lake City, UT.

Yakman, G. (2012). Recognizing the A in STEM education. *Middle Ground, 16*(1), 15–16.

Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the U.S. as a practical educational framework for Korea. *Journal of the Korean Association for Science Education, 32*(6), 1072–1086.

Zakaria, F. (2015, March 26). *Why America's obsession with STEM education is dangerous*. Retrieved from https://www.washingtonpost.com/opinions/why-stem-wont-make-us-successful/2015/03/26/5f4604f2-d2a5-11e4-ab77-9646eea6a4c7_story.html

Zylinska, J. (2009). *Bioethics in the age of new media*. Cambridge, MA: MIT Press.