

Literacy practices of experienced makers: Tools for navigating and understanding landscapes of possibility

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ABSTRACT

In this study, we explore the STEM literacy practices of experienced makers as they engage in a variety of making activities. Literacies are the ways in which individuals navigate, use, and make sense of representational texts within various contexts and for a variety of purposes. Descriptions of experienced makers' practices using representational texts can inform the ways in which educators support young people's literacy practices in formal and informal learning spaces. We interviewed 14 experienced makers—those proficient with certain tools, materials, and techniques for design and fabrication—about their making processes, and we focus our analysis on a particular literacy practice we call identifying, organizing, and integrating (IOI) information. We argue that this practice is enacted within particular making activities—e.g., ideating, tinkering—in certain ways with the purpose of sourcing and navigating information related to the maker's chosen problem. Our ultimate goal is to demonstrate how STEM literacy practices, like IOI, can serve as bridges between the meaningful work of maker-based learning in informal spaces and the curricular demands in schools, so we may broaden participation and, thus, increase equity in maker-based learning experiences.

Categories and Subject Descriptors

K.3.2 [Computer and Information Science Education]:
Literacy

General Terms

Documentation, Human Factors

Keywords

Making, Makerspaces, Maker Movement, literacy, literacies, representations, STEM

1. INTRODUCTION

The promise of making as a rich, multidisciplinary learning activity that has the ability to transform learning spaces in and out of school is gaining significant attention [11,17]. Making in education emerges from a tradition of constructionism in which educators believe that people learn better when they are able to physically, virtually, and mentally build their own objects and

representations to understand problems [3,20]. With a focus on the interactions between building and learning, educators and researchers have described compelling learning environments centered on the practices of making [9,18,28]. However, there is almost no literature that focuses on how people use literacies as they design and build [29]. We propose that examination of the literacy practices of experienced makers and descriptions of how they use representational texts can inform the ways in which educators support young people's literacy practices in formal and informal learning spaces. Particularly, we are interested in literacy practices as they relate to learning the content of STEM disciplines because of their connections to empowerment for historically marginalized groups [19,24] and because they provide a conceptual bridge to learning goals in more formal learning spaces, such as schools. Ultimately, schools must be a site of equity work and lessons from informal learning spaces can inform school pedagogy and practice.

2. THEORETICAL FRAMEWORK

2.1 Literacies as Social Practices in Making Activities

Literacies are people's facilities with consuming, creating, and manipulating multimodal, representational texts in a variety of languages, registers, and communicative modes [5]. For instance, effectively searching for information on the World Wide Web, navigating search terms, determining reliability, and reading and making sense of text, image and video—sometimes all together—are literacies [4]. Literacies are also constituted by the purposes, identities, and tools—including means for communicating—valued in that particular place and time [7,23]. Through literacy practices, people then communicate what knowledge is valued in any given social and cultural setting as they use and create shared repertoires for meaning making and frameworks for interpretation [6]. Thus, the construct of literacy practices connects particular literacy events, or time- and space-bound interactions around multimodal texts [10], with broader social and cultural values about reading, writing, and communicating [2] in ways that are mediated by local values and purposes.

How people engage in literacies is integral with why they do. Literacies then are always part of purposeful activities. We have identified at least eight goal-driven purposeful activities from our interviews with experienced makers: ideating, designing, tinkering, making, sharing, managing, teaching, and socializing. We acknowledge the somewhat artificial divide between some of these activities and that many makers would argue they bounce back and forth between activities with such fluidity that the boundaries are nearly non-existent (e.g., some might argue that making and tinkering are one and the same). However, as an

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analytical tool, it is useful to develop finer-grained descriptions of practice so that we can further articulate patterns of literacies we see among those proficient in their crafts. Further, these descriptions can be used to design supports for new and emerging makers to develop their literacies in different making activities. In this paper we focus on four of these making activities, briefly defined below:

Ideating: Captured in moments of inspiration, thinking, writing notes, and doodling. People's experiences and frames of thinking, both disciplinary and everyday, serve as fodder for creativity [12].

Designing: "The iterative selection and arrangement of elements to form a whole by which people create artifacts, systems, and tools intended to solve a range of problems, large and small" (p. 4) [11].

Tinkering: "Characterized by a playful, exploratory, interactive style of engaging" (p. 164) with materials, tools, and problems [22].

Making: "To build or adapt objects by hand, for the simple pleasure of figuring out how things work," (p. 4) [11] and often driven by one's desire to share a personally meaningful product with others.

2.2 STEM Literacy Practices

We define STEM literacy practices as socially mediated, goal-oriented practices for comprehending, producing, and manipulating representational texts related to Science, Technology, Engineering, and Mathematics (STEM) concepts. Particular repertoires of STEM literacy practices are needed to successfully navigate the demands of making. As people engage in making, they participate in a range of valued literacy practices at the forefront of STEM innovation. We suggest these are: a) posing and solving problems in the world and in the design process; b) traversing representational systems and materials, interpreting and producing representational forms; c) sharing works and knowledge with others, communicating ideas and information in new ways to different audiences; and, d) Identifying, organizing, and integrating information across sources¹. For the purposes of this paper we concentrate on describing and explaining one literacy practice: identifying, organizing, and integrating information across sources (IOI). IOI is a particularly important literacy practice because the literacies involved, conducting research on- and off-line are often the most difficult for young people, and achievement gaps among students with low socio-economic status and others persist when asked to complete similar research tasks online [15]. We posit that good scientists and engineers know how to find data or information from others, evaluate it, recontextualize it for their own research questions, and figure out what else they need to know.

Our research questions ask: What are makers' sources of information? How do makers source materials and information? How do they integrate that information into ongoing projects?

3. METHODS

This study is part of the *Investigating STEM Literacies in Makerspaces* (STEMLiMS) project, which is an ethnographic and

design-based research project examining the literacy practices of experienced and new makers, in both formal and informal settings, with the goal of designing literacy supports to encourage participation and improve equity in maker activities.

We interviewed 14 adults (9 men, 5 women from ages 20 to 57) through an in-depth semi-structured protocol. Interviews ranged from 37 minutes to 90 minutes. Participants were recruited through referential sampling. That is, we sought out experts in the field, including our advisory board, and asked them to recommend people to interview. Participants included professional artists, one who made metal sculpture and one who invented musical instruments; engineering students and professors who made things like a kayak and a firefly garden nightlight; and entrepreneurs who made products like an ergonomic keyboard and a bicycle pannier. The interviews asked these makers to talk about their history with making in general, but also asked them to describe one project in detail with particular attention to the ways in which they have used representations in their work [14]. All interviews were fully transcribed. We used a qualitative content analysis approach and began coding with a pre-existing and focused scheme to reduce data and to concentrate our analysis [16].

Focused content analysis attended to two major aspects of participants' interviews related to our research question: a) making activities and b) STEM literacy practices. The unit of analysis for both activities and practices was the meaning unit - any constellation of words or statements that related to the same central meaning (e.g., the making activity of tinkering or the STEM literacy practice of IOI) [8]. Codes from each major category (activities and practices) were then checked for co-occurrence with codes from the other categories using the qualitative analysis software Dedoose (e.g., designing x IOI). Our team of four researchers further coded those categories using thematic content analysis, comparing emergent themes through reading, discussion, and re-reading of excerpts across three interviews. Two researchers coded each remaining interview independently and then met to discuss codes and resolve discrepancies before moving on to coding the next interview.

Findings presented here focus on the co-occurrences of activities (i.e., ideating, designing, tinkering, making) and one particular literacy practice, IOI. We selected representative excerpts of themes that emerged within the co-occurrences for IOI in each of four activities. These excerpts are not intended to represent the makers' values, intentions, or approaches to making writ large. Nor are these data representative of *all* makers. Rather, they are illustrations of the ways in which makers engage these literacy practices in each of the activities of the making process we identified. Once the data were analyzed and the findings described, we distributed the written results to each participant as a form of member checking. From conversations with the participants we were able to revise and clarify the ways in which the illustrations of the themes were described. The illustrations we present in this paper are used to describe the literacy practices in greater detail so as to present opportunities for supporting the cultivation and development of these literacies in new makers. We present the themes related to IOI across the activities of making at the conclusion of the findings and discuss their implications for research on making.

¹ Please see Tucker-Raymond et al. [25] for a more complete description of these literacy practices, how they were identified, and the construction of their definitions.

4. FINDINGS

We use these findings to assert two central claims: (1) *literacy practices* are a useful conceptual framework for studying how experienced makers engage with representational texts in complex, multimodal, multiactivity, transdisciplinary domains; further, this framework structures the ways we can develop and refine descriptions of how experienced makers navigate and make sense of representational texts to do their work, which presents opportunities for connecting practices from the curricular standards (e.g., NGSS) [1] to maker activities; and (2) specifically, the practice of identifying, organizing, and integrating information exists as a tool to support *navigating* landscapes of tools, materials, and techniques and *sourcing* objects and knowledge from various communities as makers practice their crafts.

Across the interviews with 14 experienced makers, we identified the practice of IOI 32 times during the activity of *ideating* (most common practice seen in that activity), 39 times while *designing*, just 7 times while *tinkering*, and 79 times while *making*. We did not find IOI in sharing, teaching, managing, and socializing more than a few times, so we have omitted that in our analysis. We include analysis of IOI in tinkering because, while infrequent, themes emerged that helped us to understand IOI as a coherent practice across many activities. Further, a goal of our work is to eventually develop supports for new makers, and tinkering has been shown to be a point of entry for new makers [22,21].

4.1 Sources of Information

Before describing the nature of IOI within each of the activities, we present a list of the sources of information reported by our interview participants as a means for answering the first of our research questions. Sources of information across the activities of making included:

- Blogs, forums, and articles on the Internet
- Web tutorials such as *Instructables*
- How-to videos (on YouTube and other sites)
- Product specifications sheets
- Text books
- Lecture notes
- Patents and research papers
- Books, magazines, and catalogs (e.g., McMaster-Carr)
- Designed objects—where information about decisions and particular assemblages of components can be scrutinized
- Conversations with near-peers and fellow makers – in person and online

This list of sources of information is diverse and comprehensive, and we found that experienced makers have a worldview that information is available *anywhere*. The list illustrates a stance that experienced makers held toward their work: that each problem, task, or challenge was an opportunity to engage different representational “texts” to gather new information that could help them meet their goals.

4.2 IOI in Each Maker Activity

The list of sources of information is rather ambiguous, and we could argue this is a list of sources of information for any task or domain. Thus, it is *within* the particular activities that we can

understand how these sources of information are identified, organized, and integrated into ongoing projects. Thus, we present the ways in which IOI was used in conjunction with these sources of information within each of the four activities described above.

IDEATING: Within the activity of *ideating*, makers discussed ways in which they navigated various sources of information across a range of representational modalities - Google image searching, looking at videos of projects within a particular topic or genres, and examining existing physical objects (which could be considered hacking). Some illustrative examples are presented here:

“I’ll start looking up videos of ways of how to build a boat... um, cheaply, so I was Googling like different types of boats... after a week, I decided to make some sort of floating vessel for the Charles River.” - PHIL

“... the core, the core of the search is usually an image search and it’s, you know, a gut level reaction... of, you know, which of these images is resonating with sort of... intuitive sense of the direction I want to go.” - CAT

“Let’s make a new product, let’s look at everything that’s out there, um, we buy it. You know we take it apart, and we say why are these decisions made, why was it built this way and not that way. And then find the compromise between completely reinventing the wheel and leveraging the one that exist.” - SEB

Phil spoke about how his office overlooked a river, and he became interested in how he could get closer to—in a visceral sense—that body of water. He employed IOI to seek inspiration and examples of ways to build boats using videos on the internet, and this supported his efforts to refine ideas about a “floating vessel for the Charles River.” Cat is an artist who produces welded copper sculptures, among other objects. She spoke of having general ideas about pieces she might construct, and she employed IOI to navigate collections of images on the web organized around particular search terms like “Chinese dragon” to help her define and focus her ideating. The examples offered by Phil and Cat illustrate an approach familiar to many domains: using large collections of representations—photographs, videos, and information—as sources of inspiration. However, Seb and his partner, Z, exhibited a different approach: using physical objects for ideation by “hacking” them (a revered maker practice) [28] to understand a range of possible designs. They conducted this interrogation of physical devices with the particular purpose of examining decisions made by the original designers to ask “why was it built this way and not that way?” Seb and his partner, who are making an affordable DNA replicator, identified information about their chosen problem space that was embedded within designed objects. The objects served as representations of decisions made and processes used made by other makers who worked within a similar domain.

The three examples presented illustrate how makers navigate images, videos, and designed objects to identify information that brings the space of possibilities for their chosen work into focus. Their motivation for engaging IOI in this way appears to be for inspiration or possibly finding a catalyst to begin their own project. Inherent in these approaches is a starting place, or a domain of interest to anchor the quest for information. Cat knew she wanted to do something with dragons, and Seb and his partner knew they wanted to build a table-top DNA replicator. The

anchors served different purposes, from using a search term in Google to find examples and visualize an artistic piece, to learning about the technical decisions others made while working on a similar problem. But across the experienced makers we interviewed, navigating a breadth of representational “texts” (e.g., video, images, physical objects), in service of scoping, refining, and conceptualizing ideas about what to make was literacy consistently applied during ideation.

DESIGNING: In our study, makers spoke about *designing* as an activity similar to ideating, but with focused attention on a chosen project or problem. Like we found with ideating, IOI while designing involves similar anchor points used by makers to further scope their work. We present three excerpts that illustrate how makers utilize key search terms to focus and inform their designs.

*“I spent a bunch of time **pulling old patents and old research papers**, a lot of old research papers about historical keyboard designs. Um some of them describe you know angle - you know the angles that work well, the angles that don't work well.” - JESSE*

*“I invest a regular amount of time just reading stuff ... to be **familiar enough with the contours of the territory** so that when I do need to understand something I do know where to go and what the words are.” - ALEC*

*“...you get that sort of daisy chain of this leads to this, and then this person's website points to this cool thing.... it often **has words and knowledge associated with it, um, so that's my path.**” - KATHRYN*

Designing involves continued navigation of the landscape of tools, materials, and techniques, but with a honed focus on the particular project space the maker has selected. Jesse, who builds computer keyboards, describes a practice of scouring “old research papers” and “old patents” to review the history of keyboard designs as means for specifying the dimensions of the problem, such as appropriate “angles” to consider in the design. Alec, who is designing a spherical projection system to program Logo turtles in 3 dimensions, cites the example of using written texts to understand “the contours of the territory” where his work resides. His example is similar to Kathryn’s, where both share a goal of identifying key terminology in that “territory” to serve as waypoints for further navigation. Kathryn describes her “path,” in this example, where she arrives at “words and knowledge” associated with her area of interest for that project; in this case, Kathryn was designing an Arduino controlled firefly nightlight garden. These excerpts illustrate examples of experienced makers engaging text, pictures, keywords, and historical documents as sources of information for identifying critical features of the terrain in which they work. This practice involves navigating the space, similar to how we describe IOI within ideating. However, in designing, the navigation is guided by more focused goals and intentions, as compared with ideating, where navigating and learning from information provided by others serves to stimulate and define the directions in which makers choose to focus their work.

TINKERING: Working within the boundaries of a particular kind of project (e.g., Jesse making a computer keyboard) makers embark on quests to discover best practices (either on the web, or by talking with knowledgeable others), to examine the

documented mistakes that others have made to prevent their own failures, and they experiment with different parts and materials to begin addressing particular needs of their projects.

*“Very often some of the best tutorials I find are not from experts who've been doing this for 30 years, but from people **who are one step ahead of me**. People who are going to make the same mistakes that I have made, um, or help to let me avoid some of them.... it's a lot of **web tutorials from forums, books, um, sometimes a weird intuitive leap and just kind of trying it over and over and over again until I get it right.**” - JESSE*

*“I spend a lot of time looking at **best practice videos** on table saws or other things. Particularly like learning a new technique and every so often I'll be able to **find someone who's really good at the particular thing that I want to do and then I practice and work with them.**” - WALTER*

*“I think there were just different manufacturers who made a similar product, um so they had different varieties. And so I set up **all these experiments of...what things do I care about? What matters?**” - KATHRYN*

Jesse and Walter offer examples of using “near-peers,” those individuals who do similar kinds of work, as sources of information to support their work. These individuals, whether they are those with more experience, slightly higher levels of skill, or domain experts, possess valuable information about a specific problem space. They engage with these near-peers through web-tutorials and forums and through interpersonal communications that allow these humans to be rich and adaptive sources of information. Originally a DJ, Walter creates musical instruments that include record turntables that can be played in tandem with or that pick up sounds from other stringed instruments such as a harp or cello. He then performs the music. By examining “web tutorials from forums, books,” and “practicing and working with others,” these makers are able to play with ideas guided by a larger community of shared ideas, successes, and failures. From the examples offered by Jesse and Walter, the gathered information is used to do something; for example, Jesse engages in repeated trial and error—in a classic sense of tinkering with an idea, tool, or material [28,22]. Similarly, Kathryn offers a possible motivation for tinkering as an activity in which to employ IOI when she says “I set up all these experiments of ... what things do I care about?” In this sense, her practice involves information from other makers as well as her own tinkering practices as means for vetting materials and tools for her own making purposes. This playful, yet intentional, experimentation is ultimately a process of identifying, organizing, and integrating information to further her design goals.

These excerpts highlight an intersection between *doing*—working with materials, manipulating components, attempting new techniques—and a variety of sources of information that enable and support those activities. IOI as a practice for engaging a variety of representational texts—forums, videos, web-tutorials—in tinkering involves interactions with the actual objects and approaches that might be used to make a particular design. This coupling of information seeking, organizing, and integrating with the physical manipulation of an object exemplifies the notion of a practice enacted within a task or context. In other words, information is gathered, elaborated, or refined through the *doing* of some hands-on design and tinkering work, where manipulating

physical objects is an integral part of identifying, organizing, and integrating information that matters to these experienced makers.

MAKING: Finally, in the activity of making—where by far the most occurrences of the literacy practice IOI appeared in our coding—IOI was engaged as a sourcing tool for both materials and techniques but also for additional information from knowledge communities.

“We had to find you know the right suppliers, and the right parts and custom make some parts and um, eventually we got there.” - SEB

“Almost always the first step for me is to identify the community that is good at it... figuring out which one of those it is, is a mix of what community is [responsible].” - ALEC

“Did [this new component] just solve my problems and I can just stick it into my project [to improve it] or do I have to figure out how [the new component works in order to change its configuration to work with my parts]? Alright, so I take sort of a people to people approach, or a related project search to start exploring what other projects have parts that might be useful.” - AMON

“Here’s what I have, and I know what is in my inventory, and I know where [new components] can connect, and one might have a wireless means of connecting to my creation, and others might use ethernet, or a new type of cable and/or connector. I have to determine whether my new and existing components speak the same voltage... if not, I have to figure out whether it is worth acquiring or making an interface that can connect old and new parts?” - AMON

Mapping and traversing the vast terrain of parts, materials, and tools is an essential skill for experienced makers, one that involves careful vetting of the available options relative to the goals of the individual maker. We argue that IOI is a practice used to navigate the chosen project space in service of sourcing the things - knowledge and materials - needed to make something. At the level of components, sourcing of the “right parts” and “right suppliers” as Sebastian said, involves finding the parts that can be integrated with existing components in a maker’s repertoire. In addition to the objects needed to make something, Alec and Amon spoke about the importance of other makers in sourcing the information needed in support of their creative design and making. Alec finds the “community that is good at it,” which is similar to Amon’s idea of a “related project search.” Amon further elaborates this practice of IOI in making, “I know what my inventory is...I know where [new components] can connect.” When makers identify options for completing tasks—often gathered from the community “that is good at it”—they are also often aware of what components are in stock and how the assembled options either do or do not work with one’s inventory. These examples suggest a compilation of information from people, from objects, and from tools and materials that is masterfully assembled and used in service of making something. Within this making, we see IOI enacted in different ways to source the required objects, information, and approaches to assist the maker’s creative pursuit.

While the line between making and tinkering is blurry, there appears to be different goals in the two activities that we can understand by looking at the ways makers talk about IOI. When

making, this literacy practice facilitates getting the work done - completing the project - whereas during tinkering, the literacy practice occupies a space of learning about possibilities at the intersection of action and idea, where the information is understood and realized through playing with ideas and objects. Making is described as the activity where the fruits of applying IOI at other phases of the process—ideating, designing, and tinkering—are realized through the production of some artifact.

5. DISCUSSION

Literacies are social practices and in this study experienced makers report frequent and varied engagements with socially and culturally produced and maintained texts. Identifying, organizing, and integrating information from texts enables makers to interact with different communities, motivated by a purpose: making something they find personally interesting and meaningful. Grounded in this well-established phenomenon that making things engages people in motivating and important work [20] and research showing students can learn from these activities [26], we set out to explore the ways in which experienced makers interact with representations while they are engaged in activities like ideating, designing, tinkering, and making. How one interacts with representations—the literacy practices one uses— presents us with links to school curriculum-based and other literacies that can be fostered and supported through maker-based educational activities.

We summarize the themes of identifying, organizing, and integrating information that emerged in the data within each of four activities in Table 1. These themes support the claim that IOI is a practice used to navigate landscapes of possible ideas, tools, materials, and techniques. Further, IOI is a useful practice for sourcing information, including material objects and ideas, in the various activities of making.

Table 1. Emergent themes for IOI in four different activities of making

<i>Activity</i>	<i>Themes of IOI</i>
Ideating	Navigating the land of possibility at domain level (e.g., robotics) - what am I going to make and what are some potential directions I could go?; identifying information and gathering inspiration from multimodal texts.
Designing	Using various texts to narrow and scope the problem and solution; finding anchors (often in the form of keywords) in the texts that focus the design; waypoints for further navigation.
Tinkering	Information is gathered and understood through manipulation of objects and techniques; integrated into what the maker knows about the solution.
Making	Sourcing objects, information, and knowledge communities that facilitate/enable the completion of the project - a tool to support going from designed idea to constructed object.

The themes we identified of how IOI is practiced within different maker activities, while distinct in some ways, are presented as components of a relatively coherent social practice employed by makers to get their work done. While separating the makers’ processes into distinct activities is analytically advantageous for studying how literacy practices are enacted, taken as a whole, IOI is a widely used practice that appears at all points in a maker’s

work; therefore, we would argue that this is a coherent practice enacted within purposeful activity. Contained within the practice of IOI are particular component practices or sub-tasks. For example, the identification of words, images, and objects to serve as anchor-points for focusing design emerged as a theme. Here, identification can be considered a sub-task that contributes to educators' understanding of how experienced makers navigate the landscapes of possibility in their work. As such, we argue it is useful to begin articulating differences between identifying, organizing, and integrating within the themes identified in our interviews.

Identifying occurs through the scouring of different troves of information contained within conversations, images, textbooks, videos, patent documents, and conversations with others. Identifying features of a problem space by exploring other people's examples in image searches on the web shows how the sub-task of identification takes form in ideating, for example. As another example, makers reported identifying key search terms when they were designing. It appears that the task of identifying information is conditioned by the goals of the activity in which the maker is engaging at a point in time. In other words, how a maker chooses what to identify may differ from activity to activity within the overall process.

The sub-task of *organizing* involves situating newly discovered information within the overall scheme of what the maker knows relative to the chosen problem space. As Alec discussed, understanding the contours of a terrain helps him in organizing his design activity by creating a sort of road map of the project space. There is a physical aspect to this organization, literally filing and storing information in organized ways to support continued information seeking. But, we can also consider organizing from an ontological perspective, the process of making something new might involve reorganizing how one thinks about tools, materials, and domains as new information becomes available.

And finally, *integrating* appears to involve a process of taking new information and putting it to work within a particular activity. Kathryn talked about tinkering as a way to evaluate new products on the market and to determine whether she needs to care about that option within her chosen problem space. Once the new information was identified and organized, through the activity of tinkering, she decided how, if at all, that information would be integrated into her making process. While it may not be used immediately, it seems plausible that the experience of tinkering with this new thing, or idea, and the sub-task of making a determination about *where* to integrate it could support her future making when a need arises that might fit this temporarily discarded tool or material. For example, Kathryn spoke about exploring different kinds of Nitinol shape-memory alloy for her butterfly nightlight project. She eventually made a decision about what thickness and form to use, but in her tinkering with other options she gained some sense of the range of possibilities for the material. When a project requires something similar in the future, or if her first choice were to fail, there is other information integrated into what she knows about Nitinol's properties, gathered through tinkering, that she can call upon. Amon describes a practice, one of many he and the others employ, where he can literally integrate information while making as he determines whether certain parts he is sourcing will work with the parts he already has in his toolkit. In both of these examples of integrating information during a specific activity, it appears that information is put to work to help achieve some task or goal. And

while we can say that is likely true about all the sub-tasks of this literacy practice, integrating may be the closest thing to evaluating or incorporating these new ideas and information into ways of understanding the problem and the world.

In sum, describing the components of each sub-task of IOI may be useful in designing specific supports for new makers. IOI as a literacy practice, enacted in different activities, presents a way to understand how makers use different representations to go about their work. The descriptions we present, supported by excerpts from interviews with experienced makers, are an attempt to further and more precisely describe the practices of interacting with these representations with the explicit goal of supporting new makers, in school and out of school, in the same kinds of creative processes as these experienced individuals. In schools, current trends in curriculum reform driven by the testing culture emphasize small skills—e.g., identifying the thesis statement, mastering standard algorithms—which are discretized tasks taught in isolation, and that rarely are contextualized with some overarching purpose. Our data show literacy practices that include the 21st century skills that schools ask students to learn, and, for one reason or another, that they have trouble teaching in equitable ways—identifying relevant information, using keywords as anchors, comparing new ideas to existing understandings—captured in experienced makers' descriptions of their work in different activities. As such, literacy practices as a framework for studying makers can lead us to better understandings of their practice in forms and conceptualizations that provide links to the school curriculum.

6. IMPLICATIONS

Ultimately, our focus on literacy practices is a search for a place in which we can leverage opportunities for equity. Vossoughi et al. [27] acknowledged the dearth of conversations about culture and equity and made a call to the field not simply to expand and broaden access, but to also study ways of designing maker activities to be responsive to the communities of individuals who participate. Identifying ways to connect maker activities to the language and policies of public schooling is a response to concerns about access, but that alone does not address the design of responsive approaches. We argue that a focus on literacy practices allows us to identify points of connection between everyday literacy practices of identifying, organizing, and integrating information and the specific goals, approaches, and uses of IOI within the activities of making with those practices valued in schools. Building from the already rich literacy practices of youth in all manner of settings and connecting these to the particular practices we see demonstrated by experienced makers can begin to address the “how” of equity in making.

In our study, we propose the use of STEM literacy practices as a framework for understanding the work of experienced makers. The outcomes of this research are cultivated descriptions of practices that we can then identify and support in maker-based educational activities for new makers. For example, experienced makers can scan related projects and identify materials, tools, and approaches that could be useful in their own designs. We could imagine a web interface that allows users to identify related projects (through image searches, on forums and blogs, etcetera) and to organize them by materials, tools, and approaches in a way to facilitate the integration of this information into their own designs. The findings of this study—which pull from experiences

of adults in informal learning environments—can be used to support new makers in their quests to navigate the landscapes of possibility within purposeful maker activities. These supports can encourage the kinds of literacy practices described here, which connect maker activities to the curricular requirements of, for example, NGSS, to provide pathways for schools seeking to incorporate more making into their curricula. It is here where our research can make the biggest contributions to improving equity in making. Our future research in this project includes observing, designing, tinkering with, and sharing literacy supports for out of school and in school makerspace learning sites.

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