Developing Pedagogy for the Creation of a School Makerspace: Building on Constructionism, Design Thinking, and the Reggio Emilia Approach

SNADRA BECKER
University of Calgary

ABSTRACT: Making and makerspaces, current buzz words in education, have gained prominence for their ability to develop the problem solving, collaboration, creativity, and technological skills needed for the 21st century. In preparation for the creation of a makerspace within a primary school learning commons, a list of necessary pedagogical components were identified based on three distinct discourses: constructionism, as derived from the work of Seymour Papert and the team in the Media Lab at the Massachusetts Institute of Technology, the principles of design thinking in an educational context, and the pedagogy of Reggio Emilia. In examining these discourses separately, the writer determined elements common to all three. Drawing upon these common elements, guiding questions were developed that can be used to inform the creation of a school makerspace.

Keywords: makerspace, constructionism, Seymour Papert, design thinking, Reggio Emilia, collaboration, creativity, problem solving, technology, learning commons

RESUMÉ: La réalisation, l'environnement comme agent d'apprentissage et les mots à la mode communs dans le domaine scolaire sont plus importants aujourd'hui car ils peuvent résoudre des problèmes, créer la participation, inciter la créativité et apporter les compétences technologiques nécessaires pour le XXIème siècle. Afin de préparer la création de l'environnement comme agent d'apprentissage au sein des ressources courantes d'une école primaire, on a dressé une liste d'éléments pédagogiques utiles, à partir de trois considérations spécifiques qui sont :

- le constructionisme comme forme dérivée du travail de Seymour Papert et de l'équipe du Media Lab de l'Institut de technologie du Massachusetts
- les principes de la conception dans un contexte scolaire
- l'approche pédagogique Reggio Emilia.

En observant de plus près ces trois concepts séparément, l'auteur a trouvé leurs points communs. Ces points communs ont servi de support pour élaborer des questions

directrices pouvant être employées dans les renseignements sur la création d'une école avec environnement comme agent d'apprentissage.

Mots-clés: l'environnement comme agent d'apprentissage, le constructionisme, Seymour Papert, la conception, Reggio Emilia, la collaboration, la créativité, la résolution de problèmes, la technologie, les ressources courantes.

Introduction

Imagine entering a school learning commons where young students are engaged in making. You might see children programming robots, building towers and bridges with Lego, constructing wallets with duct tape, designing and printing jewelry with a 3-D printer, and using a green screen for videotaping. Making as a form of learning has re-entered pedagogical discussions, and makerspaces in 21st century learning commons are a central part of this theme.

The idea of making for learning is not new. In 1837 Friedrich Froebel opened a kindergarten that allowed children to play, invent, and explore with materials (Woodham-Smith, 2011; Resnick, 2007). In the twentieth century, Dewey (1916) recommended the first thing children should do when learning, is play and work with materials.

Now, makerspaces have become a current innovation for their constructivist approach to creating, thinking, and problem solving collaboratively (Martinez & Stager, p. 31, 2013). Originally developed as community spaces with tools for making, sharing, and learning (Hatch, 2014), there has been a move to include makerspaces as part of school learning commons (Canino-Fluit, 2014). The June 2014 themed issue of *Teacher Librarian* is all about makerspaces. Since 2013, there have been several books and articles published about the value of students making, tinkering, and playing with materials (Gabrielson, 2013; Honey & Kantor (Eds.), 2013; Martinez & Stager, 2013; Wilkinson & Petrich, 2014). Much of the work of the Media Lab and the Lifelong Kindergarten at MIT involves coding and creating, a form of tinkering using technology. The Agency by Design initiative at Project Zero, Harvard Graduate School of Education, is a multiyear study of "maker-centred learning experiences." The maker movement is trending in current educational social media and practice.

The Research Question

A primary school in Alberta, Canada, in transforming its library to a learning commons, included a makerspace as part of the plan. In discussions with administration and staff, the questions that evolved were: What factors are important to consider when creating, learning, planning, and teaching in a makerspace? Why a makerspace in the first place?

To that end, the major purpose of this inquiry was to explore the thinking around makerspaces as highly charged, personal learning environments for primary children, while identifying the key principles that one should consider when implementing a makerspace as part of a primary learning commons.

The author lead the design of a makerspace that not only encourages problem solving, creation, and collaboration among students, but also moves teachers along in their thinking about ways to promote deep learning through the use of the environment, materials, and personal reflection. By exploring the literature, the plan was to develop a teaching pedagogy for a primary makerspace, drawing particularly on the work of Seymour Papert, Design Thinking, and the Reggio Emilia Approach to guide planning.

Methodology

Initial planning began with a survey of recent practical publications detailing suggestions for the establishment and operation of community (Dougherty, 2012; Hatch, 2014) and school makerspaces (Gabrielson, 2013; Honey & Kanter, 2013; Martinez & Stager, 2013). In reviewing these texts, it was noted that the work of Seymour Papert and colleagues, in particular, Resnick, Stager, and Kafai, at the Massachusetts Institute of Technology (MIT) was often referenced. Using this as a starting point, an initial reading of these authors led to repeated mention of the terms, "constructionism, design, and the Reggio Emilia Approach. This led to literature searches around these topics, beginning with constructionism, a term developed by Papert. Design thinking, in a multi-disciplinary sense, was also explored, followed by design thinking from an educational standpoint. A review of the Reggio Approach and the elements unique to it completed the search. Though other topics, such as authentic learning, project based learning (PBL), and discovery learning (Kirschner, Sweller, & Clark, 2006; Mayer, 2004; Savery, 2006) appeared during the search phase, it was felt that exploring those

concepts would shift the focus of the research away from the ideas advanced by Papert and colleagues. They may be considered in future studies.

Traditional search engines and databases, such as Google Scholar, ERIC, JSTOR, Academic Search Complete (EBSCO), and Springer Link, accessed through the University of Calgary library, were used extensively. However social media, such as Twitter and Scoop were also sought out, to gain insight into the most current thinking around makerspaces and design thinking for educators.

In terms of peer-reviewed material, the search method began with careful reading of abstracts to determine relevance to the study. Pertinent articles were grouped according to the following topics: Seymour Papert and constructionism, design thinking, the Reggio Approach, educational makerspaces, play, and creativity.

While reviewing and compiling important notes from the literature, a list of common elements, which appeared in all three approaches was recorded. Returning to the notes and key portions of articles, supporting statements within all approaches were collected in a table to affirm the all-inclusive elements.

Literature Review

The literature review is divided into five sections, beginning with a definition of makerspaces, and the move to incorporate makerspaces within school learning commons. This will be followed by a review of the literature on constructionism, design thinking, most specifically within an educational context, and finally, the Reggio Emilia approach.

What is a Makerspace?

Mark Hatch is CEO of Techshop, a company that in exchange for a monthly membership fee, offers access to a large space and highly technological tools, such as laser cutters, 3-D printers, and lathes, to create or invent anything. Not only are community makerspaces a place to use these tools, by design they encourage collaboration and sharing of ideas. In cities around the world, makerspaces are locations for leading edge personal innovation. Hatch connects this movement to "cheap, powerful, and easy-to-use tools . . . along with easier access to knowledge . . ." (Hatch, 2013). Having time, access to materials, and people to connect with, creates opportunities for invention and creation at a high level.

This has direct ramifications for 21st century school learning environments. The Alberta Education *Framework for Student Learning* (2011) competencies of "creativity and innovation, critical thinking, problem solving and decision-making, collaboration and leadership, lifelong learning, personal management and well-being, digital and technological fluency, and communication" (pp. 3-6), embody the spirit of a maker space. And, as indicated in the 2014 K-12 Horizon Report, one of the upcoming trends is the hybrid learning design, where students "use the school day for group work and project-based activities, while using the network to access readings, videos, and other learning materials on their own time, leveraging the best of both environments" (p. 12). With the Alberta Ministry of Education's (2010) "Inspiring Education" document calling for students to have the opportunity to "think critically and creatively [...] through inquiry, reflection, exploration, experimentation, and trial and error" (p.19), classroom practices across the province should consider evolving towards more makerspace approaches to education as they directly involve students in constructing meaning through active inquiry. Imagine a school makerspace, where students having researched ideas of personal interest, could then pursue the creation of those ideas, while collaborating and sharing with others.

Hatch states, "the real power of this revolution [the maker movement] is its democratizing effects. Now, almost anyone can innovate. Now, almost anyone can make. Now, with the tools available at a makerspace, anyone can change the world" (Hatch, 2014, p. 10). Students, from a young age, could be given the opportunity to learn and practice innovation.

In a 21st century makerspace, makers have access to tools that allow them to build prototypes for problem solving on a personal level. As well as having tools to develop innovations, they also have a community of like-minded individuals, which allows for collaboration and communication of ideas. The makerspace truly is the quintessential space for "engaged thinkers, entrepreneurial spirits, and ethical citizens" (Alberta Education, 2011, p. 6).

But why Makerspaces in the School Learning Commons?

Traditional school libraries existed customarily to provide information for consumption. Large collections of primarily print materials were organized and housed in spaces that were quiet and controlled. The advent of web 2.0 (O'Reilly, 2009) technologies encouraged users to access knowledge, recreate it, and share it physically and virtually, using the technological tools of their

choosing. Web 2.0 has promoted a movement away from school libraries as places for the simple consumption of information to areas for knowledge building with spaces for creation and collaboration (Alberta Education, 2011; Calgary Board of Education, n.d.; Koechlin, Luhtala, & Loerstcher, 2011; Koechlin, Rosenfeld, & Loertscher, 2010).

The very nature of Web 2.0 technology encourages a "hands-on," collaborative approach. Students within a 21st century learning commons environment often have access to portable devices, which invites creative collaboration, both physically and virtually (Calgary Board of Education, n.d.; Koechlin, Rosenfeld, & Loertscher, 2010).

It is only recently that the concept of makerspaces as an extension of school learning commons has become prevalent. Kurti, Kurti, & Fleming (2014) connect maker education with the notion of inquiry. Loertscher, Preddy, & Derry (2013) take it further when they state, "it is a more focused, dedicated and intentional effort blending creativity, inquiry, and kinesthetics" (p. 48). Needless to say, personal inquiry, collaboration, and creating is at the heart of makerspaces within a learning commons context.

Leadership Around Making: Seymour Papert and Constructionism

What has been mentioned in much of the recently published material around school makerspaces is the work of Seymour Papert. A great deal of thinking around making as a way of knowledge building has come out of research at the Massachusetts Institute of Technology (MIT), which was conducted by Seymour Papert and colleagues beginning as far back as the 1960s. Papert's theory of constructionism builds on the constructivist theories of Jean Piaget to create a new theory of learning. It "involves two intertwined types of construction: the construction of knowledge in the context of building personally meaningful artifacts" (Kafai & Resnick, 1996, p. 1). It is in the physical construction of objects that students' learning evolves and connects. ". . . Learners construct new knowledge most effectively when they are in the process of constructing something external which they can examine for themselves and discuss with others" (Picard, et. al., 2004, p. 262). Having the ability to physically make, test, analyze, rethink, remake, and retest, as often as needed, allows for deep learning on student's terms.

New technologies that are readily available, have made it possible for students to construct objects, whether physical or virtual, which then allow them to test challenging theories easily. Papert, (1999) in inventing and using the programming language

LOGO with children, noticed that, "The contribution of technology is that it makes possible projects that are both very difficult and very engaging" (p. 3). In fact, inherent in constructionism is the physical formulation and deep mental examination of complex ideas that question and build on intellectual thinking.

The importance of collaboration is also found in a constructionist environment, where students build and connect on the ideas of others. "Collaboration needs to be mutually beneficial and based on interdependence" (Stager, 2013, p. 488-489). This collaborative mode is natural, organic, and efficacious in that by helping others to develop thinking, students are actually helping themselves.

Papert speaks of "idea power," where children are able to solve real problems, which have relevance to themselves and the world at large (Papert, 2000, p. 727). Students see themselves as societal contributors in a legitimate sense. Their thoughts and ideas have purpose, validity, and value.

Design Thinking and Makerspaces

In delving in-depth into the work of other members of the MIT Media Lab, the notion of design is often cited. Kafai & Resnick (1996) state, "Thus, there is a convergence in the fields of design and learning, with a natural intersection in the study of learning-through-design" (p. 4). In recent years, the notion of multi-disciplinary learning through design has become more prevalent in educational circles. In fact, there have been several design thinking guides developed for teachers to lead inquiry into any topic (IDEO, n.d.; MacIntosh, 2014; Ray, 2012). Though design thinking "has its roots in the innovation/design sector," (Ray, 2012, para.1), with the explosion of new and powerful personal technologies, it is being applied to multiple situations. "The subject matter of design is potentially universal in scope, because design thinking may be applied to any area of human experience" (Buchanan, 1992, p. 16). The use of design thinking as a model in education has traction because it mimics the vulnerability of authentic learning.

But what is design thinking? Gow (2012) states "the posing of a problem, perhaps elegantly framed but more likely ill-structured or open-ended - and with some constraints. Working within the constraints, problem solvers work through possible solutions and create workable models for critique, testing, retesting, and redesigning until a breakthrough is achieved" (p. 74). This, in effect, is exactly what happens within community makerspaces, as described by Hatch (2014). Design thinking is a

process that students can practice and learn within the context of a school learning commons makerspace.

In fact, Brown (2009) outlines the benefits of design thinking. They "reward risk taking, encourage designers to mix with the rest of the company, support play and new ideas, don't demonize failure, and don't overemphasize regulations or efficiency" (p. 3). Not only will design thinking assist students in developing their own process for making, it can guide teachers in designing opportunities for learning, as well.

The Reggio Emilia Approach and Makerspaces

Out of the ruins of World War II, came the inspiration for the visionary preschools of Reggio Emilia, Italy, and their notion of children as competent, confident learners (Thornton & Brunton, 2005; Wurm, 2005). When Stager (2013), speaks of the Constructionist Learning Lab (CLL), a space within a youth prison facility he created with Seymour Papert, he says, "the CLL was much more heavily influenced in its design and activity by the early childhood centers of Reggio Emilia, Italy" (p.488). A centrepiece of the Reggio Approach is the atelier, a studio or workshop, that is a space for discovery, creation, and research. As students explore and test theories of interest, they document and record the process for future reflection. Documentation is a key and important aspect of the Reggio Approach, because of its focus on process, not product. "The most impressive part of the Reggio kindergartens is the way they encourage children to reflect on what they are doing. Children in Reggio are constantly producing drawings and diagrams as they work on projects. Teachers use these artifacts to engage the children in discussing and reflecting on their design process and thinking process" (Resnick, 2007, p. 5). In a makerspace, made objects become tools for reflection, in that students can not only describe the finished product, but the steps they experienced in making it.

Other aspects of the Reggio Approach are the importance of reciprocal relationships or collaboration, and the element of time for learning (Thornton & Brunton, 2005). "We embrace an approach based on adults listening rather than speaking, where doubt and amazement are welcome factors along with scientific inquiry and the deductive method of the detective. It is an approach in which the importance of the unexpected and the possible are recognized, an approach in which there is no such thing as wasted time, but in which teachers know how to give children all the time they need" (Rinaldi, 1998, p. 115). Just as in the Reggio Emilia Approach, being open to possibilities and giving

time for multiple iterations as students work through problems are important aspects of the makerspace.

The principles of the Reggio Emilia Approach – exploring topics of interest, documenting learning, collaborating, and taking adequate time for inquiry, though geared for early childhood, are important considerations for makers of all ages.

Findings

Common Elements of Design Thinking, the Reggio Emilia Approach, and Constructionism

In careful study of the Reggio Emilia Approach, design thinking, and constructionism, the question was asked, what do all three approaches have in common? The author developed a list of pedagogical elements that link to all approaches. Following this, references to substantiate each element were located, and the information was collected in a table for further deliberation. From this table, a list of probing questions was developed to promote careful rumination around the desired pedagogies of a makerspace.

Elements	Design Thinking	Reggio Approach	Constructionism
Time Sensitive	"Michael Schurr at Riverdale appreciates the way the design-thinking "process forces you to slow down . . ." (Gow, 2012, p. 76).	"Being able to work at something for a long time is highly valued because it indicates a deeper level of involvement and hopefully of understanding" (Tarini & White, 1998, p. 377).	"Time, of course, is essential in this process. If children have enough time to go through the cycle only once, they'll miss out on the most important part of the creative process" (Resnick, 2007 p. 5).
Iterative	"It blends an end-user focus with multidisciplinary collaboration and iterative improvement to produce innovative products, systems, and services. Design thinking creates a vibrant interactive environment that promotes learning through rapid conceptual prototyping" (Meinel &Leifer, 2011, p. xiv).	"We wanted to explore things in the long term, allowing children to return to something over and over again in order to master it in their own way" (Tarini & White, 1998, p. 377).	". . . it iterates through steps of design and development so that the lessons are quickly learned and incorporated into the next cycle" (Martinez & Stager, 2013, p. 45).

Real World Problem Based	By having students begin the learning process from their own needs, the systems design approach to learning tackles the question that students often articulate and that often serves as a barrier to learning, "Why do I need to know this?" (Mehauk, Doppelt, & Schunn, 2008, p. 71).	"Projects are ways of doing work with children that in effect simulate real life" " (Wurm, 2005, p. 68).	First and most essentially, the young user was able to use the idea to solve a real problem that had come directly out of a personal project. (Papert, 2000, pp. 727).
Student Led	"The systems design process permitted students to ask their own questions for investigation in order to design their alarm systems, and it also permitted students to design their own experiments to investigate their ideas" (Mehauk, Doppelt, & Schunn, 2008, p. 80).	"Children produce their own theories, important theories from which they take inspiration" (Wurm, 2005, p. 70).	"Learners feel differently about the knowledge when they experience themselves as active participants with control over (and personal involvement in) the learning process" (Picard, et. al., 2004, p. 262).
Collaborative	"An important implication of this diversity is the need to provide support for *collaboration* in the tools" (Resnick et.al., 2005, p. 7).	"The Reggio philosophy is based upon reciprocal relationships that value others' opinions, viewpoints, and interpretations, and emphasize the importance of adults and children learning together" (Thornton & Brunton, 2005, p. 11).	". . .young people collaborate naturally and constantly in ways that adults need to be prompted to do" (Stager, 2013, p. 488-489).
Interdisciplinary	"The subject matter of design is potentially universal in scope, because design thinking may be applied to any area of human experience" (Buchanan, 1992, p. 16).	"We are too often taught to separate that which is connected, to divide rather than bring together the disciplines, to eliminate all that could lead to disorder" (Gandini, 2005, p.172).	"As in today's maker movement, connections between ideas, people, and disciplines are complex and abundant" (Martinez & Stager, 2013, p. 15).
Process Driven	"The design process is what puts Design Thinking into action. It's a structured approach to generating and	"They are not empty vessels waiting to be filled with the body of knowledge. Rather, they are vessels that are already full – full of questions and	"Emphasizing the process – the "doing" part of project work – should not cause us to lower our

	evolving ideas" (IDEO, n.d., p.14).	theories. When children can act on their questions and theories, they develop knowledge, and most essentially the ability to think deeply and make meaning" (Cadwell, 2005, p.190).	expectations for the final product" (Martinez & Stager, 2013, p. 66).
Creative	"Design thinking is a creative, individual-level process influenced by social-level factors (that is, high inspiration by others, high user-centricity, high prototyping, and low criticism by other), which includes attention, memory, and learning and leads to an aesthetically appealing object" (Reimann, Schilke, & Knutson, 2011).	Educators in Reggio speak passionately about their respect for children, for childhood and for the creative and expressive potential of all children" (Thornton & Brunton, 2005, p. 97).	"Making is about the act of creation with new and familiar materials" (Martinez & Stager, 2013, p. 33).
Constrained	"One potentially useful approach is the "design challenge": Invite people to solve a specific problem within a set of constraints . . ." (Brown, 2009, p. 4).	"The trigger for a long-term project – the provocation – may come directly from an experience or encounter that the children have had, or, on occasion, from a proposition made by one of the staff" (Thornton & Brunton, 2005, p. 14).	"Constraints make life interesting and dealing with constraints creates opportunities for ingenuity and creativity" (Martinez & Stager, 2013, p. 37).
Documented	"Don't try to create ideas in isolation, in the abstract or by using words alone. Use multiple methods. Draw – whether or not you have drawing talent. Visual representations create new insights in the form of "mind maps" that show multidirectional connections that linear verbal descriptions could obscure. Prototypes and drawings help develop ideas faster" (Brown, 2009, p. 4).	"For teachers, documentation provides the evidence of how children's learning develops. It is an important part of continuing professional development . . . For children documentation gives an opportunity for reflection and self-assessment" (Thornton & Brunton, 2005, p. 84).	"These artifacts made private thinking public and engaged the entire community in their learning. This form of documentation was beneficial to students when assessment is too often a form of judgment" (Stager, 2013, p. 488).

Teacher as Researcher	"Design thinking is about believing we can make a difference, and having an intentional process in order to get to new, relevant solutions that create positive impact" (IDEO, n.d., p. 11).	"Teachers are viewed as researchers, constantly evaluating and reflecting on their interactions with children . . . This demands of the adults an approach to life which values the unknown and welcomes doubt and uncertainty" (Thornton & Brunton, 2005, pp. 74-75).	". . . the learning environment we envisage will be good for teachers' learning as well as for students' learning" (Papert, 1999, p. 12).
Non-linear	"An important requirement for creativity is to be able to try out many different alternatives . . . it must be very easy to try things out, and then backtrack when unsuccessful" (Resnick et.al., 2005, p.4).	Learning does not unfold in a linear fashion. All the children have their own meandering paths that collide into one another, pushing each other forward, backward, and sideways. Ultimately they arrive, but in their own time" (Wurm, 2005, pp. 57-58).	"If we are trying to help children develop as creative thinkers, it is more productive to focus on "play" and "learning" (things that you do) rather than "entertainment" and "education" (things that others provide for you)" (Resnick, 2007, p. 4).
Affective	". . . a process with heart" -- a technique built around human needs and aspirations that demands deep empathy and understanding, even across geographical, cultural, and socioeconomic boundaries" (Gow, 2012, p. 75).	"Educators in Reggio speak passionately about their use of the language of emotion alongside the language of education" (Thornton & Brunton, 2005, p. 97).	"In order for the learning to become truly rooted, a person has to have a deep emotional attachment to the subject area" (Picard, et. al., 2004, p. 264).

One element that was originally considered for inclusion was that of "tells a story." Though it is an important aspect of design thinking, there was not enough evidence to suggest its importance, particularly in constructionism. It is certainly worth considering in the future as possible admission to the current list.

Discussion

This inquiry was conducted so that a list of driving questions, based on research and particular pedagogies could be developed as a guide when creating a makerspace. In studying the table of thirteen common elements and reading the accompanying quotes, and so as not to overwhelm the staff when creating a school makerspace, there was a concerted effort to limit guiding questions

to a manageable number. The author looked for themes within elements so that several elements could be combined within one question. Each question was then linked back to the elements as identified in the literature, to ensure that all elements were contained within the list of questions.

While the questions are meant to guide thinking, this list is only the first iteration of what will be a work in progress. As staff and students function in the makerspace, questions will most certainly be revisited, rethought, and revised.

Questions to Guide the Implementation of a Makerspace

Driving Questions	Elements
Do the problems to be solved, though often constrained, have personal relevance to the students so that they take the lead in solving them?	Constrained, student led, real world problem based, creative
Is sufficient time given to students to complete multiple iterations of their ideas?	Time sensitive, iterative, non-linear, creative
Is there adequate opportunity for natural collaboration while making?	Collaborative
Is the work multi-disciplinary so that there is ample opportunity for connected learning?	Interdisciplinary
Do students take ownership in documenting the story of their learning?	Documented, process driven
When assessing, is the non-linear process valued over finished product?	Process driven, non-linear
Do teachers view the makerspace as an opportunity to learn and take risks?	Teacher as researcher
Is there a feeling of happiness exuded throughout the space, even though the learning is challenging?	Affective, creative

Though the questions can be answered yes or no, attention was paid to wording them in such a way that evidence could be articulated to substantiate the yes or no answer. The following is an example of an evidential response to the driving questions:

Possible Evidence in Response to Driving Questions

Driving Questions	Evidence
Do the problems to be solved, though often constrained, have personal relevance to the students so that they take the lead in solving them?	Students are asked to create an advertisement that encourages people to visit the country of Tunisia.
Is sufficient time given to students to complete multiple iterations of their ideas?	Students have plenty of time to construct and make changes to improve the strength and stability of a bridge.
Is there adequate opportunity for natural collaboration while making?	Students offer up suggestions to each other to make their games using magnets more fun.
Is the work multi-disciplinary so that there is ample opportunity for connected learning?	The creation of instruments (science), study of cultural music, (social studies), writing of music and lyrics (music, language arts), understanding musical notation (math).
Do students take ownership in documenting the story of their learning?	Students photographed problems and solutions they encountered, when building bridges.
When assessing, is the non-linear process valued over finished product?	A teacher took no photographs of the finished bridges. The emphasis shifted to the learning process while building.
Do teachers view the makerspace as an opportunity to learn and take risks?	Changes were made with the Lego town build based on problems as they arose.
Is there a feeling of happiness exuded throughout the space, even though the learning is challenging?	Not only were there smiles, engaged workers, thoughtful voices, the space has very much a workshop feel, where students verbally express enjoyment in the task.

As evidenced by the previous example, school staffs could use these questions as a catalyst for discussion. It is the hope that the resulting discussion will lead teachers into reflecting deeply about the elements they put in place in their own constructionist environments. It may also give them the opportunity to consider what works and what changes need to be implemented for greater success.

Though a good beginning, next steps may include employing the driving questions in the development of a rubric that teachers can adopt as a more specific assessment tool for their own school makerspace.

Conclusion

All three theoretical approaches discussed in this paper have a great deal to offer staff in schools who are looking for guidance in the development of a makerspace. The melding of these complementary perspectives on collaborative, student led, problem-based, interdisciplinary approaches to learning can provide a rich base for a makerspace prototype. The key contributions of this paper are: 1) Providing background in potential makerspace pedagogies; 2) Presenting a list of common elements between those pedagogies and: 3) creating a list of driving questions with exemplars for staff use. It is hoped that this article will serve as a practical starting point for developing the pedagogical underpinnings necessary in the creation of any educational makerspace.

REFERENCES

Agency by Design (2014). In Project Zero online. Retrieved from http://www.pz.gse.harvard.edu/agency_by_design.php

Alberta Education. (2011). *Framework for student learning: competencies for engaged thinkers and ethical citizens with an entrepreneurial spirit*. Edmonton, AB: Alberta Education. Retrieved from: http://education.alberta.ca/media/6581166/framework.pdf

Alberta Education. (2010). *Inspiring education: A dialogue with Albertans*. Edmonton, AB: Alberta Education. Retrieved from: http://ideas.education.alberta.ca/media/2905/inspiringaction%20eng.pdf

Brown, T. (2009). *Change by design: How design thinking transforms organizations and inspires innovation.* getAbstract with permission from Harper Business.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues*, 8(2), 5-21.

Cadwell, A. (2005). Pedagogical Patterns. In L. Gandini, L. Hill, L. Cadwell, & C. Schwall (Eds.), *In the spirit of the studio: Learning from the atelier of Reggio Emilia* (pp. 175-194). New York, NY: Teachers College Press.

Calgary Board of Education. (n.d.). *Library to learning commons*. Retrieved from http://cesd-libraryvisioning.wikispaces.com/file/view/Library_Learning_Commons_Implementation_Guide.pdf

Canino-Fluit, A. (2014). School library makerspaces: Making it up as I go. *TeacherLibrarian*, 41(5), 21-27.

Creswell, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: SAGE.

Dewey, J. (1916). *Democracy and education*. New York, NY: Macmillan.

Dougherty, D. (2012). The maker movement. *innovations*, *7*(3), 11-14.

Hatch, M. (2014). *The maker movement manifesto: New rules for innovation in the world of crafters, hackers, and tinkerers*. New York, NY: McGraw-Hill Education.

Gandini, L. (Ed). (2005). The whole school as an atelier: Reflections by Carla Rinaldi. In L. Gandini, L. Hill, L. Cadwell, & C. Schwall (Eds.), *In the spirit of the studio: Learning from the atelier of Reggio Emilia* (pp. 169-174). New York, NY: Teachers College Press.

Gabrielson, C. (2013). *Tinkering*. Sebastopol, CA: Maker Media, Inc.

Gow, P. (2012). An experience of" yes": Independent schools begin to explore and exploit the power of design thinking. *Independent School*, *71*(3), 72-79.

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York: NY: Routledge.

IDEO. (2012). *Design thinking for educators.* Retrieved from http://www.designthinkingforeducators.com/toolkit/

Johnson, L., Adams Becker, S., Estrada, V., and Freeman, A. (2014). *NMC horizon report: 2014 K-12 edition*. Austin, TX: The New Media Consortium.

Kafai, Y. & Resnick, M. 1996. *Constructionism in practice: Designing, thinking and learning in a digital world*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86.

Koechlin, C., Luhtala, M., & Loertscher, D. V. (2011). Knowledge building in the learning commons. *Teacher Librarian*, *38*(3), 20-26.

Koechlin, C., Rosenfeld, E., & Loertscher, D. V. (2010). *Building the learning commons: A guide for school administrators and learning leadership teams*. Salt Lake City, UT: Hi Willow Research & Publishing.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The philosophy of educational makerspaces: Part 1 of making an educational makerspace. *Teacher Librarian*, 41(5), 8-11.

Lifelong Kindergarten. (n.d.). Retrieved from https://llk.media.mit.edu

Loertscher, D. V., Preddy, L., & Derry, B. (2013). Makerspaces in the school library learning commons and the uTEC maker model. *Teacher Librarian, 41*(2), 48-51, 67.

MacIntosh, E. (2014, May 11). *The design thinking school*. Retrieved from http://notosh.com/what-we-do/the-design-thinking-school/

Martinez, S. L. & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59(1), 14.

Mehauk, M., Doppelt, Y., & Schunn, C. D. (2008). Middle school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, 97(1), 71-85.

Meinel, C. & Leifer, L. (2011). Design thinking research. In Plattner, H., Meinel, C., & Leifer, L. (Eds.), *Design thinking: Understand-Improve-Apply*. Berlin, DE: Springer.

MIT Media Lab (n.d.). Retrieved from http://www.media.mit.edu

O'Reilly, T. (2009). *What is web 2.0?: Design patterns and business models for the next generation of software*. Sebastopol, CA: O'Reilly Media, Inc.

Papert, S. (1999). *Vision for education: The caperton-papert platform.* Retrieved from http://www.papert.org/articles/Vision_for_education.html

Papert, S. (2000). What's the big idea? Toward a pedagogy of idea power. *IBM Systems Journal*, *39*(3.4), 720-729.

Picard, R. W., Papert, S., Bender, W., Blumberg, B., Breazeal, C., Cavallo, D., ... & Strohecker, C. (2004). Affective learning—a manifesto. *BT Technology Journal*, *22*(4), 253-269.

Ray, B. (January 3, 2012). *Design thinking: Lessons from the classroom*. Retrieved from http://www.edutopia.org/blog/design-thinking-betty-ray

Reimann, M., Schilke, O., & Knutson, B. (2011). Product differentiation by aesthetic and creative design – A psychological and neural framework of design thinking. In H. Plattner, C. Meinel, & L. Leifer, (Eds.), *Design Thinking:Understand-Improve-Apply*[Books24x7 version]. Retrieved from http://library.books24x7.com ezproxy.lib. ucalgary.ca/assetviewer.aspx?bookid=51379 &chunked=1&rowed=2

Resnick, M. (2007). All I needed to know (about creative thinking) I learned (by studying how children learn) in kindergarten. Proceedings from *ACM Creativity and Cognition Conference*, Washington, DC: ACM.

Resnick, M., Myers, B., Nakakoji, K., Shneiderman, B., Pausch, R., Selker, T., & Eisenberg, M. (2005). Design principles for tools to support creative thinking. *Research Showcase @CMU*. Pittsburgh, PA: Carnegie Mellon University.

Rinaldi, C. (1998). Projected curriculum constructed through documentation

Progettazione: An interview with Leila Gandini. In C. Edwards, L. Gandini, G. Forman (Eds.), *The hundred languages of children: The Reggio Emilia approach-advanced reflections* (pp. 113-125). Westport, CN: Ablex Publishing.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning*, *1*(1), 3.

Stager, G. S. (2013). Papert's prison fab lab: implications for the maker movement and education design. Proceedings from *12th International Conference on Interaction Design and Children* (pp. 487-490). New York, NY: ACM.

Tarini, E., & White, L. (1998). Looking in the mirror: A reflection of Reggio practice in Winnetka. In C. Edwards, L. Gandini, G. Forman (Eds.), *The hundred languages of children: The Reggio Emilia approach–Advanced reflections*, 375-403.

Thornton, L. & Brunton, P. (2005). *Understanding the Reggio approach: Reflections on the early childhood approach of Reggio Emilia*. London: David Fulton Publishers.

Wilkinson, K. & Petrich, M. (2014). *The art of tinkering*. San Francisco, CA: Weldon Owen.

Woodham-Smith, P. (2011). *Friedrich Froebel and English Education* (Routledge Library Editions: Education, Vol. 145). E. Lawrence (Ed.). London, UK: Routledge.

Wurm, J. (2005). *Working in the Reggio way: A beginner's guide for American teachers*. St. Paul, MN: Redleaf Press.

Address for Correspondence
Sandra Becker
PhD Student, Learning Sciences
Werklund Doctoral Fellow
Werklund School of Education
University of Calgary
sandra.becker@ucalgary.ca