Ends and Means: A Framework for Design, Make, and Play Learning Activities

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Abstract

This paper reports on the development of a comprehensive framework for categorizing existing learning activities and programs in design, make, or play learning methodologies. The terms design, make, and play are reviewed in the literature along with associated terms. Features that are common between the learning methodologies and that differentiate between them are identified. The learning methodologies differ primarily with respect to the explicit goals of the learning: design is focused more on ends, play is focused more on means, and make blends the two types of goals. The goals give rise to different processes, which are then also a source of difference between the learning methodologies. A framework that identifies these different features in terms of goals and processes is proposed, represented using a table format, and applied to existing programs.

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Part 1 – Introduction and Approach

The goal of this paper is to develop a comprehensive framework for categorizing existing learning programs into the learning methodologies of *designing*, *making*, and *playing*. All three methodologies can be used to structure activities for young people that help them to develop the knowledge, practices, interests, and confidence that are necessary to move them beyond simply being users of technology toward being creative innovators of that technology. However, it is important to understand how these methodologies are similar and different, their relative strengths and weaknesses, and their contrasting and complementary roles in facilitating learning. Doing so may help to optimize the design of learning environments that appeal to the full range of young people with a wide range of backgrounds and interests.

The approach taken in this report is to begin by describing some different components of the learning methodologies in isolation and then work up to a comprehensive framework that in the end will differentiate the three learning methodologies. First, I will review research that defines design, make, play, and related terms in order to set a foundation for the framework. Second, I will summarize the terms into a number of key features that characterize the full space of types of activities, and identify the particular features that differentiate the learning methodologies. Finally, I will apply the framework to a range of documented learning programs in order to illustrate how the framework may be used as a classification tool. Taken together, the framework should be useful both to designers of learning environments who are interested in understanding and evaluating their own programs and to learning researchers who are interested in specifying the types and qualities of interactions of learners situated within learning environments.

Part 2 – Terms and Associated Research

One of the goals of this report is to bring together some of the many terms that are used to describe exploratory activities in which learners can engage. In order to identify a broad set of types of activity, it will be useful to consider research that is focused both at the individual level (i.e., observations of learners engaging in particular behaviors or actions) and at the program level (i.e., carefully designed instructional stages or activities within the overall sequence of a program). Considering definitions for each of these terms will then provide the basis for comparing between them and for building a common framework.

Design

There are many different types of design, including engineering, architectural, digital media, and artistic design. Each type of design has its own types of knowledge and practices (Carvalho, Dong, & Maton, 2009), but all have commonalities in terms of goals and processes. The main discipline of design considered in this report is engineering and technological design, but aspects of artistic and creative design will also be considered in order to understand some of the commonalities across the design disciplines.

Engineering / Technological Design

Engineering and technological design is well represented in empirical learning research. In addition to learning about engineering and technology, design is a learning methodology that is commonly used to help students learn science, and to target the complementary nature of design and inquiry. Engineering and technological design play a prominent role in the recently-released Framework for K-12 Science Education (National Research Council, 2011). That framework highlights the importance of design as a way for learners to understand the man-made world in addition to the natural world, as well as the relationships between them. Examining some of the learning research that has focused on design can help to define design as a learning methodology and be explicit about its components.

One such learning program is Design-Based Science (DBS; Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005). In DBS, Fortus et al. use the term "design" to refer to any adaptation of the environment using tools and materials to suit a need (Fortus et al., 2004, p. 1082). They then go on to make a distinction between everyday design (with a lowercase "d") and professional Design (with an uppercase "D"), where the latter is more formal and explicit, including explicit stages and processes along with criteria to determine whether the final design is acceptable. Figure 1 displays the learning cycle from the DBS curriculum. The DBS curriculum includes explicit stages not only for making the artifact, but also for defining the problem or context, considering multiple ideas, and then analyzing the produced artifact.

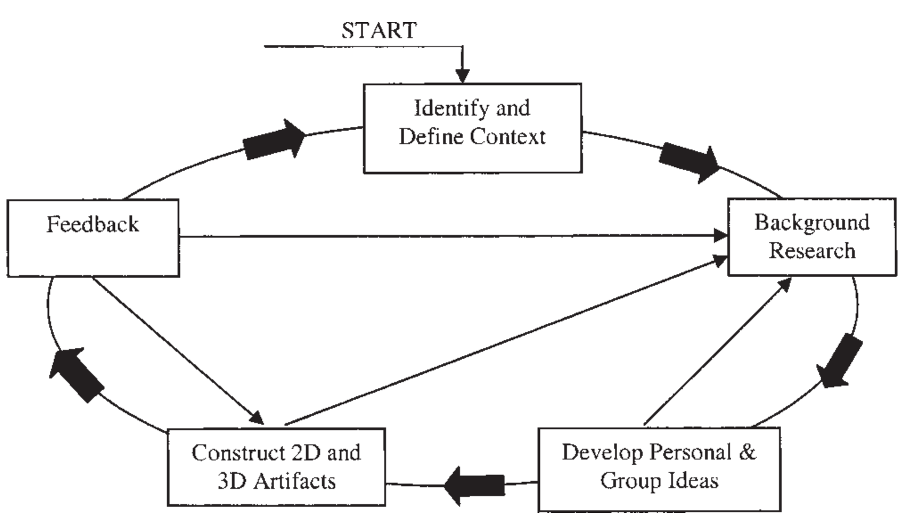

Figure 1. The Design-Based Science (DBS) learning cycle. (Source: Fortus et al., 2004, p. 1086)

Other learning research using design as a learning methodology takes a similar position as the DBS program about the definition of design. In Learning by Design™ (LBD) curricula, Kolodner et al. (2003) use design in the context of creating a working artifact or device:

> *By designing, we refer to the full range of activities that a professional designer (e.g., engineer, architect, industrial designer) engages in to fully achieve a design challenge—understanding the challenge and the environment in which its solution must function well; generating ideas; learning new concepts necessary for its solution (through a variety of means, ranging from asking an expert to reading to carrying out an investigation); building models and testing them, analyzing, rethinking, and revising; and going back to any of the previous steps to move forward, repeating until a solution is found. (Kolodner et al., 2003, p. 504)*

In other work with LBD curricula, Puntambekar and Kolodner (2005) take a similar position that design consists of four nonlinear and iterative phases: (1) understanding the design challenge or problem, (2) gathering information, (3) generating a solution, and (4) evaluation (Puntambekar & Kolodner, 2005, pp. 190-191). Puntambekar and Kolodner break this down further into seven subprocesses that learners needed to be given explicit support in doing in order to create and learn from their final artifact. Considering the LBD and DBS programs together, one important aspect of design is the final product itself. This product must satisfy a particular need and so the goal of the activity is not to produce just anything, but rather, to produce a solution that is effective and reliable with respect to a defined problem. In keeping with this goal, another important aspect of design is the inclusion of a number of highly systematic and analytical processes that help to ensure the solution can be realized and meets the specified need.

The DBS and LBD programs are similar, but other learning programs take a broader view of design. In the City Technology project, Benenson approaches design more from a technology perspective and as a result makes a number of important additional distinctions (Benenson, 2001, pp. 730-732). First, Benenson suggests that many people think of technology simply as computers or “high technology”, but that technology actually encompasses much more of the things that surround us everyday and everywhere, such as containers and utensils. Second, Benenson suggests that many people think of design as the artifact that gets created, but that is only the hardware component. There is also a software component, which again Benenson suggests is only narrowly conceived of as computer software. Benenson's more inclusive definition of the software component of design includes the plans, procedures, programs, and schedules designed to make use of hardware. Design is then not just about producing something physical, but also about producing systems and environments. Finally, Benenson also distinguishes between technological design that is typical in competitions and authentic design. In the competitions, the design is artificially focused on a single criterion or variable, whereas an authentic design effort must satisfy multiple, often conflicting requirements, and so must be evaluated using trade-offs and value judgments. Benenson goes on to suggest that there are three fundamental aspects in technological design, which include (1) solving a problem of some sort, (2) considering different possible solutions (since according to his definition of design, it is not an authentic design problem unless there are many possible solutions), and (3) an explicit effort to test the design against some agreed-upon evaluation criteria with respect to the original problem. The technology perspective on design thus helps to specify further the essential aspects of design both in terms of the outcome and the process. Taking into account technological design, the outcome of design continues to be the creation of some solution even if that solution is not limited to a physical form. In addition, the process of design must include aspects that help explicitly to define the problem and to evaluate the solution.

Artistic / Creative Design

Considering another discipline of design may help to test the boundaries of design and to form a more inclusive and explicit definition. Bernstein conducted her dissertation research on a program to help girls develop technological fluency, called the Robot Diaries project (Bernstein, 2010). When trying to appeal to girls specifically, Bernstein suggested that creative design might provide an alternative to engineering design. Bernstein (2010) in her review of the literature suggested that a fundamental distinction between artistic or creative design and engineering design was in the goals of the activity. Both types of design involve idea generation and exploration, as well as the actual production of some artifact. However, engineering design focuses on functionality as the primary outcome, while artistic design focuses on aesthetic and expression as legitimate ways to evaluate the resulting artifact. Bernstein describes how the Robot Diaries program includes a formal engineering process, but instead of having a functional goal, it also includes an expressive goal of creating a robot that can communicate emotions in a story. This hybrid approach of both including typical engineering processes, but focusing alternatively on an expressive rather than functional criterion, helps to solidify some common aspects of design. The common aspects are (1) the production of some artifact or solution for a particular goal and (2) the use of systematic, analytical processes to generate and evaluate that artifact or solution with respect to the particular goal.

Make

Making is becoming increasingly popular (Diana, 2008) in the form of do-it-yourself websites and magazines, community workshop spaces (hackerspaces), and hands-on museum settings (e.g., The Tinkering Studio at the Exploratorium). However, to my knowledge, making is an activity that is currently less represented in empirical learning research and so it is more difficult to define precisely. Some related terms from the learning research literature might be helpful to distinguish making from designing.

Trial and Error / Guess and Check

One possibility is that making and designing are fundamentally very similar, except that making may utilize less systematic, less rigorous, and more informal processes for generating solutions. Research on strategies used by learners in math problem solving suggests that a guess-and-check or trial-and-error strategy is common among novice students (Stacey & MacGregor, 1999). In many cases, learners don't use guess-and-test strategies haphazardly. On the contrary, learners may use guess and check with a solid, implicit sense of what the things they are manipulating correspond to in the situation and the likely effects of those manipulations on the outcome (Johanning, 2004, 2007; Nhouyvanisvong, 1999). However, a defining characteristic of guess-and-check strategies are that the iterations proceed closer to the goal without utilizing explicit relationships between the manipulated features and the outcome, and so do not include the level analysis involved in design processes. If making involves more guess-and-test strategies, then this would suggest that some processes may differ between designing and making, even if both types of activity have the goal of producing an artifact or solution to a particular problem.

Tinkering

A process more commonly associated with making than guess-and-test is tinkering. An often-cited example of tinkering is the autobiographical experiences of Andy diSessa, a well-known physicist and learning scientist. diSessa (2000) recounts his early experiences taking apart and building radios as contributing to his "intuitive" knowledge of physics. He describes how his exploration and testing were less about systematically creating new and more powerful knowledge, and more about getting his current project to work: "Hypotheses were typically low level—in response to 'Why doesn't this stupid thing work?' rather than about any grand principle" (diSessa, 2000, p. 70). He goes on to suggest that these tinkering experiences did not lead directly to learning particular bits of formal scientific knowledge. Instead, his activities with the radios formed the foundation for later learning by helping him to recognize common patterns of change in physical systems. When he was later introduced to school-taught knowledge about physics he was able to recognize those patterns of change embedded in the formal concepts, representations (equations, graphs, etc.), and laboratory activities. Thus, the intuitive knowledge that he developed through years of tinkering served as a foundational support for making sense of the formal physics knowledge, but did not generate that formal knowledge directly. However, the goal of creating a working solution was a salient aspect in this account of tinkering.

Other studies have investigated tinkering in studies of student interactions within formal learning settings. Richardson (2008) studied tinkering in the context of freshmen engineering design teams. She defined tinkering "as the manipulation of equipment, tools or materials using one's hands to change, create or better understand the inner workings of a gadget, small device, or to create a new gadget or device" (Richardson, 2008, p. 55). Additionally, she made the distinction between exploratory tinkering and regulatory tinkering, where the latter includes using materials only as instructed and the former involves some sort of use beyond the explicitly-instructed use, such as using or modifying the tools for other applications or goals beyond the current task. Jones et al. (2000) made a very similar distinction when investigating learner interactions within pairs of students working together in a science lesson at the second grade and fifth grade level. Jones et al. were interested both in the interactions between the learners within the pair and also their interactions with the materials and tools that were made available to them (e.g., graduated cylinders, scales, microscopes, seeds, and worms). In that study, "playing" with tools was defined as using the tools without a specific purpose, versus "tinkering" with tools, which was defined as using the tool purposefully outside of the teacher's directions. They found that boys were more likely to both play and tinker with the materials than girls were. In these formal studies, the definitions suggest that an essential aspect of tinkering is about going beyond "sanctioned" uses of an object. However, tinkering still maintains an aspect of intentional, goal-directed use.

Maker Methodology

One recent research description of making does exist (Silver, 2009) and helps to clarify the more exploratory tinkering processes with the explicit focus on creating working outcomes. Although examining a broader range of making literature would provide a more reliable assessment of the essential aspects of making, examining this particular research description will help to make salient some of these aspects. Silver (2009) relates his personal story of developing an open-source toolkit for transforming human touch into music using drawing instruments (e.g., a pencil). In reflecting on his experience, Silver suggests some of the defining characteristics of a maker methodology. One characteristic is that makers design specifically for "hackability, adaptation, and customization" (Silver, 2009, p. 244). Underlying this characteristic is that the maker mentality is only partially about the resulting built object, and is at least as much about the process of doing the building, adapting it, and sharing it. In some ways, the how-to instructions and toolkit packages that commonly result from making activities are similar to Benenson's (2001) ideas about the software component of design artifacts in that they are focused on the plans and procedures for making use of hardware. However, the goals of the making activity are less about creating an efficient solution to a particular problem and more about appropriating solutions for personal purposes and interests, as well as engaging in the actual appropriation process itself (Akah & Bardzell, 2010). Given this greater emphasis on the process itself as one of the goals of the activity, it makes sense that the maker community has tended to advocate for the creation of toolkits that are open source, use cheap and common materials, are shared early on in their process, and are rapidly iterated and repurposed. These sorts of processes make it more likely that others will engage with and participate in the making activities. Design focuses on the goal of producing effective and reliable solutions to particular problems, so from that perspective the systematic and analytical processes included in design help to ensure the solution is of high quality. However, in making, although there is some emphasis on the resulting product, the shared commitment to valuing the process itself has its own importance.

Play

There is a vast array of contemporary and historical research on the role of play in learning. In a recent review, Fisher, Hirsh-Pasek, Golinkoff, Singer, and Berk (2011) adopt a definition of play that encompasses both free play and guided play within the broader term *playful learning*. They suggest that while determining a clear definition of play or explicit criteria for distinguishing play activities is difficult, most researchers agree that play involves activities that are “fun, voluntary, flexible, involve active engagement, have no extrinsic goals, involve active engagement of the child, and often contain an element of make-believe” (Fisher et al., 2011, p. 343). A key aspect of play from this definition is the no extrinsic goals. The learner has intrinsic goals that are tightly aligned with their play activity. However, although engaging in play activities may result in learning and may even result in the creation of some artifact, the learner is not engaging in those play activities thinking about how that learning or product may serve some useful purpose outside of the immediate activity. A useful distinction arises when comparing play activities with exploratory activities (Weisler & McCall, 1976). Although both play and exploration activities are motivated primarily by the learner initiating and directing the activity, in exploratory activity the goal of the learner is primarily to understand a particular object, situation, or event. In contrast, in play activity the learner is focused much more on using the object or surroundings for their own immediate purposes and interests. That is, in exploration the learner may be driven by the question, "What can be done with this *object* or *situation*?" In play, the learner is driven by the question, "What can *I* do with this object or in this situation?" As such, the focus in exploration is on the object or situation itself, and in play the focus is on the individual and their actions and experiences at that moment in time.

In line with this view of play as having no extrinsic goals, Pellegrini (2009) has suggested that the most important criteria for determining whether a child's activity is play is whether the child emphasizes the means over the ends and the nonfunctional quality of their activity. In other words, in play activities the child is not concerned with the creation of a particular product or outcome. Nor are they concerned with what benefit that they can get from participating in the activity. Dewey (1990) took this same position about the primary importance of the learner's own goals in defining play:

> *Play is not to be identified with anything which the child externally does. It rather designates his mental attitude in its entirety and in its unity. It is the free play, the interplay, of all the child's powers, thoughts, and physical movements, in embodying, in a satisfying form, his own images and interests. (Dewey, 1990, p. 144)*

This is not to say that there are no benefits to the learner, and in fact there may be a number of valuable learning benefits that result from playing in a carefully constructed play space or guided play activity. This is only to say that the learner is not engaging in the activity for the purpose of obtaining those benefits, and in many cases may not even be aware of those potential benefits. The child engages in the activity voluntarily with their personal interests foremost, and so is not bound by conventional notions of the object or situation.

Approaching a task with only intrinsic, nonfunctional goals enables learners to have the flexibility to engage with the object or situation in ways that are exaggerated, segmented, and nonsequential. Pellegrini (2009) also suggests that it is precisely this lack of concern for the usefulness of the activity that enables the learner to experiment with the forms and sequences of objects and situations. When the result of the activity doesn't have to serve some functional purpose in the future the learner is much freer to try out different ideas, practices, and roles without fear of failure. In turn, these informal experiments ideas, practices, and roles are what are responsible for many of the learning benefits that do result from play. Taken together, these definitions suggest that an essential aspect of play is the focus of the learner on their own immediate experience, rather than any potential outcomes, products, or results of that experience that may serve them or others in the future. It follows that the learner is more likely to engage in processes that are purposefully unconventional and unsystematic.

Part 3 – Putting Together the Framework

This section will explore some of the features that could be used to differentiate and classify design, make, and play learning activities.

Knowledge Aligned to the Activity

Although on the surface the design learning methodology seems to have a number of differences between the make and play learning methodologies related to the level of rigor employed by the learner, the level of rigor actually employed within design is not uniform. Informed design refers to design that more explicitly incorporates theory or general knowledge to guide the design activity at multiple points (Burghardt & Hacker, 2004). Within engineering design, theory knowledge may be used to generate possible solutions; theory knowledge may be used to explain the successes or failures of implemented solutions; and new theory knowledge can be generated (through inquiry) to help improve successive iterations and revisions of the design product. Uninformed design may include all the essential components of design (identifying key aspects of the problem with criteria, considering multiple solutions, and analyzing the solutions with respect to the criteria), but not rely on theory knowledge explicitly. Uninformed design may lead to more frequent use of trial and error or guess and test strategies when generating and revising the design, which may in turn lead to inefficient processes and suboptimal designs, but still contain the essential aspects of design. In other words, it may that uninformed design distinguishes between novice and expert forms of design even though both are design (Crismond, 2001). However, informed design is likely the type of design that is found in instructional settings where the goal is to learn science in addition to design and so connecting to theory knowledge is essential. Informed design is also the type found in professional design settings (Gainsburg, 2006) where the knowledge of the participants is more expert and the consequences to failed designs are more severe.

It may be that there are similar variety of forms within the making and playing learning methodologies with respect to how much they are informed by theory knowledge. Considerable research supports the role of play in learning especially with young children (Fisher et al., 2011), which suggests that at least under some conditions learners participating in play engage in sophisticated thinking and learning within their play activities even if that is not their explicit goal. In addition, play can look very sophisticated in its own right when the participants bring to the activity considerable amounts of prior knowledge (experts) and when the environment includes powerful tools and supports. For example, it might be beneficial to think of Google Labs (http://www.googlelabs.com/faq) as the play space for employees of Google, separate from their primary product design activity. Google Labs is a source for fresh and innovative ideas that, although not entirely well formed and ready for the market, do explore the potential for future products and also may have benefits (in terms of skill development and idea generation) to the employees who pursue those ideas (for fun). Play spaces and making activities may be carefully constructed to align with important theory ideas (Barab, Gresalfi, & Ingram-Goble, 2010; Rieber, 1996) in terms of eliciting the learner's relevant prior knowledge and making it so that informed ideas are more likely to be productive for the learner's own purposes. Since there is a lot of variability within the learning methodologies and since each learning methodology can explicitly align with theory ideas, this leads to the conclusion that the difference between the learning methodologies is not in the potential for incorporating generalized theoretical knowledge, and possibly not the level of learning that results either (although the route of learning may be different).

Scaffolding within the Activity

Another possible distinguishing feature between the learning methodologies may be the level of scaffolding that is used to guide the learner's activity. Similar to the feature of activating theory knowledge, on the surface it may seem that design would tend to be associated with more explicit guidance and make and play would be associated with more freedom and openness. However, also similar to the previous feature, closer inspection suggests that the level of guidance may not be associated strongly with a particular learning methodology. Scaffolding refers to how materials, tools, and other objects can be included in the environment to broaden what learners consider (open up) or to constrain what they consider (close off). Scaffolding also refers to how the teacher, facilitator, or some more-knowledgeable other can take on different roles, such as helping the learners to pursue whatever they choose at their own request (support), gently observing and encouraging learners to move in particular directions (guided), or more explicitly laying out a path for learners to follow (directed). There can be both learner-directed design (where the learners are the ones primarily responsible for identifying the problem, generating solutions, and implementing them) as well as guided play (where the teachers, facilitators, or more-knowledgeable others play a central role in influencing the direction of activities by way of choosing what materials to make accessible, infusing targeted suggestions and questions, and providing feedback). Overall, this suggests again that there is more variability between programs within each learning methodology in the type and amount of scaffolding provided than there is between the learning methodologies.

The Goals of the Learner (key difference)

Given that the type of knowledge that is activated and the level of scaffolding provided are not features that distinguish between the learning methodologies, what features do distinguish between them? In considering the review of the terms from the previous section, I suggest that the primary distinction between play and design is in the types of *goals* of the activity that the learner adopts (e.g., focused on producing a particular solution versus focused on engaging in a process) and in the types of *processes* employed to pursue those goals (e.g., the level of analysis focused on optimizing a particular solution or the level of openness to pursue unconventional paths). I will focus more on the differences in processes between the learning methodologies in the next section. In terms of the goals, in any activity the goals of the learner may vary from producing something as an outcome of the activity to valuing the process or experience itself. In design, the goal is much more the former, while in play the goal of the activity is much more the latter. Making activities maintain both goals.

To be more concrete, the National Academy of Engineering Committee on K-12 Engineering Education used the definition for engineering design, “as a purposeful, iterative process with an explicit goal governed by specifications and constraints" (Katehi, Pearson, & Feder, 2009, p. 82). One common feature of all the design work reviewed (from the engineering design to the technological design to the creative design) is that the goal from the learner's point of view is to produce a solution to a particular problem or need. The learners are focused on the ends of the activity, and this ends-focus is the primary influence for determining what criteria that a learner would use to judge the success of their activity. When focused on producing a particular solution the criteria that are most useful are ones that evaluate whether the solution is effective for the particular need for which it was designed. In other words, the learners participating in a design activity are going to be focused on whether their end product is *functional*. Learning in making activities also have functional goals, as they are trying to get a solution that works for some problem, even if the problem may not be as well defined. Learners in play activities, on the other hand, do not have functional goals. They are engaging in the activity not for what they can get out of it, and taking on particular ends-focused goals would likely change the experience for the learning to something that was not play-like.

In addition to the particular thing that is produced from the activity, a related goal also focused on the ends of the activity is that the learner may also be concerned explicitly with what they are learning from the activity. That is, in design activities the learners not only want to build a particular solution, but also want to develop particular skills or understandings. Design is intentional and purposeful in this way as the learners focus on how their activity will result in some explicit *knowledge*. Making also has this character even if the knowledge that is gained is less formal. Learners in making activities may be more concerned with how do I get this thing to work rather than any generalized knowledge. Again, though, play does not have this ends-focused goal. To reiterate from before, learners engaged in play activities may certainly end up creating particular artifacts and developing particular skills or understandings, but those are not explicit goals that they hold while engaging in the activity. If those sorts of functional or knowledge goals do become realized, then it was because of some implicit and emergent result of the activity more than the learner's explicit intentions and purposes.

Another type of goal learners may have while engaging in an activity is a *personal* goal related to the learner's individual interests and concerns. This type of goal is always present in making and playing activities since even when those activities are scaffolded or constrained in some way, an essential aspect is that the learners pursue the directions that they choose to pursue (Akah & Bardzell, 2010). In design, on the other hand, although some programs may be set up to encourage students to articulate their own personal needs and design a solution specifically for their interests (Mehalik, Doppelt, & Schunn, 2008), that is not a typical or essential aspect of design activities.

Finally, a fourth type of goal is the learner engaging in the activity specifically to have fun, an *enjoyable* goal. Play maintains this goal much more strongly than the other two learning methodologies. Learners in a play activity choose the activity specifically for having fun above all other goals and if they begin engaging and are not having fun, then they are likely to disengage quickly. Enjoyment may certainly be present in both design and making activities, but as before, this type of goal is not the primary driving force for a learner to choose those activities or to sustain them.

These four types of goals are listed in Table 1, which is a representation for laying out the entire framework for classifying learning programs to the learning methodologies. The table lists and describes the different features on which learning programs may vary. The top half of the table lists the different goal types just described. The bottom half of the table focuses on the processes that learners use when participating in the activity. These processes will be described in the next section. This table also provides a shortened label for each feature that will be used when applying them to example programs. The last three columns of the table indicate the features that are associated with each type of learning methodology. A "+" indicates that inclusion of that feature in the learning program is strongly suggestive of which learning methodology that activity should be classified; whereas a "–" indicates that a learning activity in that methodology is unlikely to have that feature present (or that having that feature present may be inconsistent with that learning methodology). The background color of the cells provides a visual way to see the group of features that are associated with each learning methodology: red indicates the design learning methodology, green indicates the make learning methodology, and blue indicates the play learning methodology. Some features are in common between more than one of the learning methodologies (e.g., *Functional* – the goal of participating in the activity is to create a working solution to a problem), and other features are associated with only one or two of the learning methodologies (e.g., *Enjoyable* – the goal of participating in the activity is to have fun), and so can be used to distinguish between them.

The Processes Used (key difference)

Since learners engage in the different learning methodologies with different goals in mind, this has implications for the types of processes they use to pursue their goals. In some sense, the processes are not essential to a particular learning methodology directly, but when taking into account the learner's goals some processes will be more effective for ends-focused goals and other processes will be more effective for means-focused goals. Hence, the processes tend to be associating with particular learning methodologies.

The first process that differentiates the learning methodologies is actually *defining* the problem to be solved. In activities that are much more means-focused such as play activities or in activities that ends-focused only to some extent such as make activities, then defining the problem is not a central issue. In design, however, defining the problem is of central importance. Although in many cases of design activities in school contexts, the problem that needs to be solved is fairly well defined for the learners, this does not mean that all design problems are laid out so well from the beginning. In the processes of authentic design (Mehalik & Schunn, 2006) even when the initial goals are ill-defined (which is likely more common in authentic design), a key process in design is to engage in an analysis process to better understand the problem, to constrain the problem, and to provide a complete problem specification that can be used to evaluate solutions. Similarly, after initial solutions to the problem are created, in design there is usually some additional reflective activity that looks critically at the solution to determine whether it meets the requirements specified in the problem. A clear definition of what counts as success is essential for doing this reflective analysis. The process of defining the problem is not always easy and is not always at the beginning of the activity for novice designers. For example, high-quality implementations of design suggest that it is necessary to engage in a process that refines the learner's thinking about what counts as a good artifact over successive iterations of their design with increasingly functional and more complex criteria (Penner, Lehrer, & Schauble, 1998; Sadler, Coyle, & Schwartz, 2000). This use of well-defined goals to constrain activity and then to reflect back critically on the results seems antithetical to the core aspects of play activity. In making activity, although the learners are focused on getting something that works, their process is unlikely to include a narrowing of the definition of the problem. In fact, successive revisions are likely to open up the problem by connecting the solution to additional creative uses.

Other processes are used in design activities to help ensure that the ultimate product of the activity reliably and efficiently solves the problem. The most common of these processes is simply to cycle or iterate the solution such that each successive solution is better than the previous one in solving the particular problem. This sort of focused search of the space of possible solutions is not a process that would be present in play activities since there isn't a particular goal that the learners are trying to solve. Although the type and even quality of the activity is likely to change over time in play activities, this process is not explicit or intentional as it is in design. Other processes focused on the goal of creating higher quality solutions over time include examining existing solutions, generating and considering multiple solutions, and functional decomposition, where the learner breaks up the larger problem into smaller subproblems that can be approached individually. All of these processes can be grouped together into a process referred to as *implementation*, which reflects an ends-focus that is present in design and making, but not in play.

Two processes that are less common in design, but are more characteristic of the make and play learning methodologies are what can be referred to as *diverge* and *transform*. In both make and play activities the processes are less structured and so pursuing new directions is encouraged. But more directly, processes of sharing, appropriation, and customization are central components in making (Akah & Bardzell, 2010; Silver, 2009) because the goals of making activities are focused both on the ends and the means. Divergent thinking may have some value within engineering and technological design (Cropley, 2006), such as when periods of divergent thinking (when lots of loosely connected ideas are considered) are then combined with periods of convergent thinking (when those ideas are critically analyzed to determine the most suitable solution). As a concrete example, the Learning by Design units encourage periods of "messing about" early on in the design process, where learners are encouraged to explore materials without a goal of having to create working artifacts and without focusing in particular solutions (Kolodner et al., 2003). This activity sets the learners up for the more focused and goal-driven engineering design and science inquiry activities that follow. But those divergent processes are not an essential aspect of design, and are more common and more valued in play and making activities. Similarly, transforming objects in situations in unconventional, nonstandard ways are a hallmark of both make and play activities. Again, that sort of informal experimentation may at some later point lead to better designing, but is not characteristic of design directly.

Similar to the different goal types, the different processes are listed and described in Table 1, along with an indication of which processes are associated with which learning methodologies.

Table 1. The features of learning activities used in the framework and the association of features with the learning methodologies.

Feature	Label	Description	Design	Make	Play
Goals					
Functional	FN	The result of the activity is an effective, beneficial solution to a particular problem.	+	+	–
Knowledge	KN	The result of the activity is learning of some explicit and reliable skill or understanding (theory/formal or craft/informal).	+	+	–
Personal	PE	Participating in the activity is focused on personal interests, concerns, and directions.	–	+	+
Enjoyable	EJ	Participating in the activity is regarded as fun.	–	–	+
Processes					
Define	DF	Make explicit criteria to evaluate solutions and constraints to narrow the solutions that are considered.	+	–	–
Implement	IM	Create a solution that reliably performs a particular act (likely involves many sub processes, e.g., decomposition, revision)	+	+	–
Inform	IN	Draw on, revise, or acquire general knowledge (theory/formal knowledge or craft/informal) to guide the activity.	+	+	+
Diverge	DV	Become immersed in the activity and readily pursue new (divergent) directions as they arise.	–	+	+
Transform	TR	Exaggerate, segment, resequence, and repurpose typical objects and behaviors.	–	+	+

Part 4 – Applying the Framework

Since the features of the framework have been presented, it is now possible to apply those features to existing programs as examples of how the framework can be used to classify those programs into the learning methodologies. Table 2 illustrates this process. Each of the programs is rated on each feature of the framework and then classified based on those ratings into one of the three learning methodologies. Each row of the table consists of one program or learning activity. A "+" rating indicates that feature is present in the learning program, and a "−" rating indicates that the feature is not present in the program. The background color of the ratings in each row indicates the learning methodology to which that feature is commonly associated. The background color of the final classification for the program indicates which methodology that learning program should be classified into according to the framework: red indicates the design learning methodology, green indicates the make learning methodology, and blue indicates the play learning methodology.

It will be important to consider both prototypical cases and boundary cases of each of the learning methodologies. The prototypical cases will help to assess the extent to which the framework captures the essence of the learning methodologies and how they differ from each other. The boundary cases will help to assess the limits of the framework, possibly leading to the addition, deletion, or revision of some of the features. The boundary cases may also highlight programs that purposefully employ multiple learning methodologies and so will illustrate how this framework can be used to make that boundary-crossing explicit. An interesting case is the artistic design program of the Robot Diaries project (Bernstein, 2010). It has both elements of design and making, suggesting that some programs may cross boundaries between the learning methodologies. The Robot Diaries project is given an intermediate color between red and green to indicate this.

This table can be updated with additional learning activity designs as they are identified, but should serve as an example for applying the framework in order to classify programs into the learning methodologies.

Table 2. Classifying learning programs using criteria that distinguish between the design, make, and play learning methodologies.

Learning Program	Age/Grade Level	Setting	Content	Goals				Processes					Final Classification
				FN	KN	PE	EJ	DF	IM	IN	DV	TR	
Design-Based Science (Fortus et al., 2004)	High school grade 9-10	High school physical science class	3 units (e.g., *Extreme Structures)*	+	+	–	–	+	+	+	–	–	Design (Eng/Tech + Informed)
Learning by Design (Kolodner et al., 2003)	Middle school grade 6-8	Middle school physical and earth science classrooms	Set of units (e.g., model way to manage erosion on a hill)	+	+	–	–	+	+	+	–	–	Design (Engr/Tech + Informed)
City Technology (Benenson, 2001)	Elementary and middle school grade K-8	Various school classrooms	5 units (e.g., *Environmental Analysis & Design)*	+	+	–	–	+	+	+	–	–	Design (Engr/Tech + Informed)
Robot Diaries (Bernstein, 2010)	Middle school age 9-14 (girls)	Homeschool setting	Robotics, electronics, expressing emotions	+	+	+	–	+	+	+	–	–	Design (Engr/Tech + Art/Cre)

Table 2. (Continued)

Learning Program	Age/Grade Level	Setting	Content	Goals				Processes					Final Classification
				FN	KN	PE	EJ	DF	IM	IN	DV	TR	
Drawdio Toolkit (Silver, 2009)	All ages	Web, interactive fashion show, museum exhibits	Electronics, improvisable human to nature interfaces	+	+	+	−	−	+	+	+	+	Make
My Magic Story Car (Bellin & Singer, 2006)	Preschool age 4-5 (at-risk, low-SES)	Any childcare setting (parent home care, day care centers, etc.)	Make-believe play, and literacy (e.g., phonological awareness)	−	−	+	+	−	−	+	+	+	Play

Part 5 – Potential Uses for the Framework

How can this framework for design, make, and play learning activities be used to support future research, evaluation, and development? In terms of developing learning activities, the framework may help guide designers of learning environments by helping them to be explicit about the type of activity that they think is most appropriate for their situation. The framework would then help the designer to focus on the features of their activity that are most critical. For example, a designer of a play activity would likely be concerned with the learners having fun in the activity, but may be less aware of the learner's personal interests and concerns as being a central component of a learner's experience in play activities generally. This issue may be especially relevant as the designers of the learning activities try to make a productive transition between free play and guided play (Fisher et al., 2011) by adding in scaffolds and directions to the activity that serve the designers goals for what the learners should attend to and learn. Appreciating that enjoyment and personal interests are the most salient goals of play activities from the learner perspective, designers may be more sensitive to the impact of the additional guidance that they build into the activity. Similarly, when designers of guided play activities consider the processes that they want to support in their activity, they may be wary of supports that attempt to narrowly define the problem for the learner. They may also seek out ways to support the learner in taking the activity into new and unexpected directions and to transform the objects and behaviors within the activity in ways that weren't anticipated by the designers.

In terms of research and evaluation of learning activities, the framework may help guide investigations into identifying best practices within each type of learning activity, but also to understand the relative strengths and weaknesses of the different learning activities. For example, studies could compare two different design activities and that have contrasting approaches for helping learners to define the problem that needs to be solved and what counts as a good solution. The framework helps to highlight that contrast as being important within design activities and the results of such a study could identify ways that are more productive for learners in helping them to consider more reasonable solutions, evaluate their effectiveness, and revise their ideas.

Looking across activities within the different learning methodologies may be another useful direction for research. One possibility is that the different learning methodologies are more or less appropriate for different types of learners, such as learners who have not experienced success in more typical forms of instruction. It may also be possible that the different activities result in very different types of learning. With the framework as a guide, it may be possible to design learning activities that approach similar content but in very different ways. Comparing the outcomes of the different activities in terms of their impact for different types of students on learning, interest, dispositions, and other outcomes may lead to a better understanding of the most productive role for each type of activity. Moving beyond direct contrasts, another possibility is that the different activities could be used in some sequence in which learners went back and forth between them depending upon their goals at the time. For example, in the Learning by Design (LBD) program (Kolodner et al., 2003), learners move back and forth between design and inquiry with "ritualized" activities within each so that students are aware of the different types and their different purposes. It may be that play activities are more appropriate at some points within a larger sequence of learning activities, and at other points make or design activities are more appropriate. If the learning activities do indeed lead to different outcomes, but all of those outcomes are desirable, then it may be the case that having a balance of the different types of learning activities available for every learner is ideal.

Part 6 – Discussion and Next Steps

Although the current framework is still tentative and open for revision, the list of features in terms of goals and processes appears to be productive for ultimately being used as an accessible tool for classifying a range of activities into the learning methodologies. The table representation of both the features themselves, and their application to different programs helps to summarize and communicate the patterns within the framework.

Ultimately identifying more example programs and applying the framework to those programs will likely be the most important source for improving the framework. Doing so will lead to modifications and refinements that should make the framework more coherent and more stable. Soliciting examples from learning designers in the field who are aware of both prototypical and boundary examples will be necessary to move the framework forward.

A particular difficulty is the general terms of design, make, and play, which make conducting database searches for appropriate literature problematic. However, with continued searching and recommendations from researchers in the field, it should be possible to identify appropriate literature within each learning methodology.

An additional challenge is that the differences in setting between the different programs may ultimately make it harder to make fair comparisons between the learning methodologies. Although both design and play have rich traditions in school-based programs, it is not clear whether making activities do. Making activities in many cases are not neatly packaged activities, but rather emergent activities that are distributed and used over the web. Identifying examples of making programs developed for in-school, after-school, or museum settings would be especially ideal for including as examples in the framework. Further, since first-hand experience with the activities is limited, an important criteria for inclusion in this report is that there is some paper or report the describes the program and activity in some detail, including the reasoning behind the design choices made by the learning designers.

This framework is just one step in helping to bring together the diverse communities that that are represented by the design, make, and play learning methodologies. As participants in the communities realize their differences and their commonalities, they may better be able to leverage their relative strengths in providing a range of opportunities for a diverse set of learners in many different places and forms. Understanding the landscape of opportunities may help to ensure that all learners have access to learning activities that help them to develop their own interests and concerns along with productive knowledge and skills.

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