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Capstone in Education

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A Portfolio of Thoughts on Education and Informal Learning Environments

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INTRODUCTION

> I suspect that everybody – not just you and I genuinely wants to share and feel at home with the cumulative and increasingly coherent awareness of nature that is the traditional harvest of scientists and artists.
>
> - Frank Oppenheimer (1976, p. 8)

I believe that today we are seeing a diffusing of the traditional boundaries between discipline and discipline, between expert and non-expert, and between teacher and student, largely in terms of what activities we, as a general public, feel entitled to engage in, and what claims we feel entitled to make about the world. With this cultural shift, we are also seeing dissolving of the hierarchy of education, and especially its placement within our lives. The pursuit of learning, especially for post-school adults, is becoming more and more a frequent, leisure-based activity. Web services now connect people with a desire to learn to other people willing to teach, and new kinds of domain-specific community spaces that support curious, self-driven learners are proliferating across the globe. Alongside these cultural innovations, support, funding, and respect for more traditional and established informal learning institutions, especially science museums, is growing as well. To put it optimistically, it is an exciting time to be someone who enjoys learning.

This portfolio is a collection of thoughts on the concepts Thinking, Understanding, Learning, and Educational Design. With this portfolio, I aim to apply my own theoretical twist on how thinking, understanding, learning, and educational design are best understood in the domain of education, and how these concepts serve and are served by the kinds of learning activities promoted by informal learning institutions such as science museums. Further, I make a case for a definition of learning that, I think, runs counter to views inherent to much of the

formal educational policy and practice that presently exists. I argue in favor of the idea that successful learning is heavily rooted in play and exploration within informal contexts.

In chapter 1, I outline my views on thinking. I argue that thinking is essentially a process of building meaning, and that there are multiple modes of thinking, which we internalize through our interactions within various culturally situated contexts.

In chapter 2, I outline my views on understanding, emphasizing that understanding is largely based in performance and situated action, but also acknowledging that developing new understanding relies on our previous experiences of enacted understanding. I also provide detail on the relationship between understanding and thinking, namely the role of thinking in building new understanding.

Chapter 3 is divided into two sections, a section on learning, and a section on learning in informal environments. In the learning section, I focus my discussion on two important aspects of learning: the development of intuitive, or hidden, knowledge, and the kinds of experiences that serve to motivate engagement and create committed learners. I also discuss the difference between understanding and learning, and how the development of understanding contributes to the process of learning.

In chapter 4, I discuss some general principles and topics of consideration for designing informal learning environments, specifically museum-based environments. I discuss how my concepts of thinking, understanding, and learning can inform the informal educational design process.

Chapter 5 is a case study in informal learning. In it I detail my efforts building an exhibit about circuits, and conduct a discourse analysis of people's interactions with the exhibit. I link this analysis to my discussion of learning and educational design.

Chapter 6 is a reflection on the lesson on informal learning that I taught the Capstone in

Education class. I talk about the decisions that went into the design of the lesson, how the lesson went, the feedback I received on the lesson, and my ideas for refinement of the lesson.

Finally, after the conclusion and references section, I include a postscript, which is reflection on my learning experience in Capstone in Education, written in class on the last day of class.

1

THINKING

There are a multitude of modes with which we engage with the world, solve problems, and build meaning for ourselves. We might, for example, approach a difficult problem by stepping through its elements in a logical way, or we might engage with another person by trying to empathize with them. These modes are all, essentially, ways of thinking. Thinking is a process of building meaning, by which I mean it is a process of creating interpretations, perspectives, or frames, of the world. We build meaning by interrelating various artifacts, which are things like ideas, images, and experiences. These artifacts themselves are situated within and descendent from pre-existing socio-cultural meanings. They are the raw materials with which we build meaning.

Language can be seen as a tool with which to represent and name artifacts, and with which to build and convey meaning. Gee (2004, p. 52) states that "language itself is built to allow people to take and communicate different perspectives." He elaborates:

> ...words and grammar exist to give people alternative ways to view one and the same state of affairs. Language is not about conveying neutral or 'objective' information; rather it is about communicating perspectives on experience and action in the world, often in contrast to alternative and competing perspectives...humans give meaning to language by running simulations of our previous experiences...Human language is built to support human thinking, both of which are perspectival.

Language is able to represent the artifacts and contain the meanings that we think and communicate. But language is merely one way of encapsulating artifacts in a conveyable way. As Gee says, "experiences are stored in the mind/brain, not in terms of language but in something like dynamic images tied to perception both of the world and of our own bodies, internal states, and feelings" (p. 49). We can certainly represent and/or work with these dynamic images through

language, but we are not limited to language in terms of how we think. A visual image in one's mind could also be considered an artifact, as could a sound, a feeling, and a memory. Meaning can be created from all of these things. To reiterate, thinking is the process of mixing these artifacts, binding them together, and testing out these relationships in order to make meanings.

Another good example of what I mean in my use of the term artifact involves the use of tools (physical objects, which themselves convey implicit knowledge). Gee discusses the process of learning to cook as involving these types of tools. He states, "proper tools are made available as well, many of which carry 'knowledge' learners need not store in their heads' (p. 12). He uses a pan as an example. The pan carries its own knowledge, that of the necessity of distributing heat evenly in baking. As a tool, it enforces a certain perspective on the world; it carries meaning. In the same way that words from others help us challenge and enrich our own thinking, we incorporate physical objects, external from our minds, in the act of making meanings, or as Gee says, being perspectival. So my use of the term artifacts encompasses a very wide range of things. Anything that can be used to make a perspectival statement, implicit or explicit, about the world is an artifact. Therefore thinking is not something that just occurs in the head, but is rather a process of meaning making in which we engage ourselves that can take many forms, be solitary or communal, and be internal or external.

Meanings are not static interpretations. They enable us to dictate courses of action, and to predict behaviors and results. Gee (p. 52) calls this process of prediction a simulation:

> We have experiences in the world, including things we have experienced only in the media...These are our raw materials, like the game with which the gamer starts. Based on these experiences, we can build a simulated model...The model we build is not 'neutral.' Rather the model is meant to take a perspective...

We run simulations, that is to say, we play out what the consequences of those meanings in terms of what they state will happen and how it will happen. In turn, we act on the world in ways that

are in concert with how we run those simulations, i.e. what our meanings suggest to us about how to act in the world. As Gee states (p. 52), "The world offers us raw materials for our simulations and our simulations cause us to act in the real world in ways that change it to better resemble or model simulations." The relationship between artifacts and meanings is cyclical. Identifying artifacts and creating relationships between them is what allows us to build meaning, and in turn, these constructed meanings enable us to identify, find, and create new artifacts or recast familiar ones. When we consider the phrase "push one's thinking," this reveals the implicit idea that thinking is not the driver of itself, but rather is initiated. Thinking necessarily involves a re-examination of existing meanings that the thinker holds, and new artifacts and meanings spur this re-examination.

Thinking is always situated within a context, and encounters with artifacts within this context are the drivers of thinking. These encounters can occur in the form of dialog, explorations of a tool, readings of a text, etc. In addition to external contexts, thinking is situated within an internal context. This internal context may be the prior experiences and meanings that a thinker brings to an external context and that an external context brings to the surface for the thinker. Barnes (Mercer & Hodgkinson, 2008, p. 3) states that

> ...most of our important learning, in school or out of it, is a matter of constructing models of the world, finding out how far they work by using them, and then reshaping them in the light of what happens. Each new model or scheme potentially changes how we experience some aspect of the world, and therefore how we act on it.

The internal contexts that we hold in our minds and bodies influence how we come to perceive and think with new meanings and artifacts. In an analysis of classroom talk, Barnes further states (p. 6):

> The talk, for all its incompleteness, seemed to be enabling the girls to use their existing knowledge of people and behaviour to construct a meaning for the words of the poem...I began to realise that it was not only in reading

> literature that we need to bring existing knowledge to give meaning to what we hear or read. All understanding depends on this...

In educational contexts, encounters that drive thinking which are dialogical in nature are especially significant. As I have previously stated, our thinking is not limited to the artifacts and meanings we possess internally, but rather those that we have access to both internally and externally. With this in mind, dialog can be thought of as one of the primary tools for accessing the artifacts and meanings that are present in other peoples' minds. Lipman (2009) describes communication between people as "that sort of interpersonal experience in which each participant causes the other to think" (p. 90). This is why dialogue can be such a valuable process for thinking, especially in educational contexts, because by engaging in dialog participants are able to share in the rich and diverse array of meanings held by their peers, therefore exposing their own meanings to possibly new and unfamiliar contexts. Lipman (p. 93) notes the presence of this quality in one such culture of dialogic practice he identifies as a community of inquiry.

> The community of inquiry is in one sense a learning together, and it is therefore an example of the value of shared experience. But in another sense it represents a magnification of the efficiency of the learning process, since students who thought that all learning had to be learning by oneself come to discover that they can also use and profit from the learning experiences of others.

The value that interpersonal interaction holds as a driver of our thinking extends beyond just the sharing of experience and novel meaning. Our interactions with others expose us to new processes and structures for thinking, that is to say, new ways of finding and creating relationships between artifacts. An example of this process is, as mentioned above, the ability to engage in thinking of a dialogical nature. This thinking process is discursive and rhetorical, it involves creating and playing with relationships through internal and external expressions of language. Indeed, Billig (1996, p. 141) makes the suggestion that "humans do not converse because they have inner thoughts to express, but they have thoughts because they are able to

converse." Billig's treats thinking itself as a dialogical act:

> ...we learn to reason through dialogue, for our forms of reasoning will be forms of dialogue, especially argumentative dialogue...we may divide ourselves, in order to become our own critics and admirers. To use the words of George Mead, 'all mental activity' involves the ability to take 'the role of another', and, by taking the role of both proposer and critic, we are able to arrange our own internal debates.

Dialogical thinking is just one facet of a many-sided phenomenon, however it is an excellent example of what is, in many cases, an important thinking process to have command of, as it enables us to create and convey powerful meanings. Another obvious example, perhaps a sub-member of discursive thinking, is the structured, logical manner of thinking associated with scientific and philosophical thought, otherwise referred to as *reasoning* of various sorts.

Langer (1995, p. 220) makes a case for the importance of literary thinking, or as she terms it, "horizon of possibility thinking." She defines this as (p. 214):

> ...a literary orientation can be characterized as *exploring a horizon of possibilities* [authors emphasis]. It explores emotions, relationships, motives, and reactions, calling on all we know about what it is to be human. In a literary experience, thinking is guided by two goals: on the one hand people make sense of new ideas in terms of their understanding of what the whole is about, but they also use their new ideas to reconsider the whole as well. The sense of the whole involves an ever-emerging horizon of possibilities that enrich but also partially elude the person's understanding because that understanding is always open to further possibilities.

Langer's literary thinking is a process of relating artifacts that is very different from the argumentative and logical processes outlined above, which try above all else to reach a superior, and often narrow or limited, conclusion.

Wegerif (2008, p. 284) makes a case for the creative aspects of reasoning, which I will identify here as yet another example of a thinking process:

> ...dialogical reason is characterised by the creation of a space of reflection between participants in which resonance between ideas and images can occur. To put this idea more simply: creativity is a more essential characteristic of human reason than explicit reasoning.

Lipman (2009, p. 92) describes dialog in communities of inquiry in a different way: "the moves

that are made to follow the argument where it leads are logical moves, and it is for this reason that Dewey correctly identifies logic with the methodology of inquiry." To Wegerif (2008), the sharing of ideas in a dialog is not limited to logical, argumentative form of inquiry. Rather, it can also encompass narrative, talk that is cumulative as it progresses rather than refutative, and resonance between similar experiences. He states (p. 283),

> Creative play with words and ideas assumes an orientation of mutual trust and support, a sense in which each participant knows that what he or she says will be accepted...the participants try to make the best sense they can of a different perspective, and this effort seems to open up a space of reflection in which ideas can resonate together.

The essential point I am trying to make is that there are many ways of thinking, that is, many ways of drawing relationships between artifacts to create meanings. These relationships can be logical connections, they can be emotional resonances, some can be eliminated in favor of a single superior relationship that creates a more correct meaning, or all can be kept in tension to explore a horizon of meanings. This speaks to my claim that thinking is situated within socio-cultural contexts. Not only that, it is developed within them, because people do not possess strength and utility in these various processes of thinking from birth onwards, rather they develop them through cultural learning experiences.

In summary of Vygotsky, Wegerif states that "the ability to perform cognitive tasks when acting alone stems from a prior socialisation process when the same or similar tasks are performed with the help of others" (p. 280). He is saying that we learn these processes of reasoning and talking through our interactions with others. Only then can they be internalized into processes we use in our own thinking. By engaging in different kinds of dialog, we develop the ability to simulate those dialogues internally. By participating in a guided, horizon-opening discussion about a literature source, we perhaps gain the willingness and ability to search for multiple interpretations of things we encounter in our own lives. In other words, our ability to

think in different ways is scaffolded by our interactions with other, often more mature, thinkers. And experimenting with different thinking processes enables us to create meaning in new ways. Barnes (Mercer & Hodgkinson, 2008, pp. 4-5) conveys this notion as well:

> At the centre of working on understanding is the idea of 'trying out' new ways of thinking and understanding some aspect of the world: this trying out enables us to see how far a new idea will take us, what it will or will not explain, where it contradicts our other beliefs, and where it opens up new possibilities.

The process of meaning-making can take many forms, as I have argued, and it is not always an internal, language-based and logic driven process. Humans are constant thinkers, by nature of the fact that we are always situated within multiple threads of context and culture, and we encounter many artifacts in these contexts that challenge, reinforce, and enrich the meanings that we have developed and are developing. As we learn new ways of thinking, and experience new interactions with people, tools, and texts, we expand the possibilities of meanings that we are able to develop from the artifacts that we have access to, and increase the reservoir of meanings and artifacts that we draw from in order to make sense of the world.

Gee speaks to the importance of giving learners experiences that help them learn better (2004, p. 52):

> Once we see how important being able to simulate experiences in our mind is to comprehending oral and written language, we can see the importance of supplying all children in schools with the range of necessary experiences with which they can build good and useful simulations for understanding things like science.

It is one thing to read a textbook on a given subject, without having any prior knowledge or experiences which can be easily related to that subject, and another to read the text and be able to draw on a rich personal history of experiences that the text can help explain in further detail. As I will discuss in chapters 3 and 4, informal learning institutions are in a powerful position to provide experiences like this for learners. Experiences that enable them to relate artifacts of

content knowledge to artifacts they already possess in order to create meaning, and therefore be able to think in ways that promote the development of powerful understandings. If we enable people to be able think at a higher level in various content domains, then they will have much more success learning and developing positive identities in relation to those domains. Informal institutions are able to do this because they often play a dual role as both educational institutions and places of leisure. People go to them to have fun, and naturally this pre-disposes them to have more memorable experiences, which can then be resurfaced in future—perhaps more formal, perhaps not—educational contexts.

2

UNDERSTANDING

I have defined thinking as the process of building meaning, and will define understanding as the ability to perform actions such as thinking, working with materials, making predictions about nature, etc. These understanding performances constitute our abilities in regards to making moves appropriate to specific contexts. For example, the ability hit a baseball in a way appropriate to the context of a baseball game constitutes an understanding. The various relationships between meanings one possesses or creates, explicit or implicit, constitute different understandings, while the process of modifying and re-working these relationships constitutes thinking. Additionally, building understanding by way of thinking necessarily involves incorporating our prior experiences of enacted understanding.

Is understanding something that can exist as a dormant resource, a framework of knowledge than can be called upon or activated in various situations, or is it something else? Perkins (1998) argues against the notion that understanding is something that is stored, waiting to be called upon for action, a notion that is widely used in the educational literature through concepts such as prior knowledge and mental models. He claims that the performance itself should be considered the understanding, rather than a manifestation of a pre-existent, internally stored structure. However, Perkins' ideas and those he criticizes are not irreconcilable. The idea that we possess internal representations of understanding is reasonable and not without merit, as is Perkins' argument that understanding really lies in the process of action. I argue that understanding is, as Perkins claims, the performance itself. However, these performances are not temporary things, i.e. the understanding manifested in a performance does not disappear after a performance has ended, only to resurface when the performance is begun again. Rather, the

experience of the enacted understanding stays with the person who produced the performance. It becomes an artifact that we can use in thinking, i.e. in running simulations and building meaning. These experiences are stored and connected internally, as the idea of a mental model suggests, and are drawn upon during subsequent performances and tryouts of new understandings.

In Gee's (2004, p. 49) discussion of language and thinking, he cites several sources from the cognitive psychology literature which speak to my argument:

> It used to be, and still is in some quarters, a standard view in pyschology that the meaning of a word is some general concept in the head that can be spelled out in something like a definition...However, today there are accounts of language and thinking that are quite different. Consider, for instance, these two quotes from some recent work in cognitive psychology: 'comprehension is grounded in perceptual simulations that prepare agents for situated action' (Barsalou, 1999a: p. 77); and 'to a particular person, the meaning of an object, event, or sentence is what that person can do with the object, event, or sentence' (Glenberg, 1997: p. 3). These two quotes are from work that is part of a 'family' of related viewpoints...While there are differences among the different members of the family, they share the viewpoints that language is tied to *people's experiences of situated action in the material and social world*.

I will make the jump to say that not only is language tied to "experiences of situated action," as Gee says, but that all action is tied to prior experiences of action, especially action that is performed in order to display understanding. Gee continues (p. 50):

> We build our model simulations to help us make sense of things. Sometimes this does not work all that well. For example, every time I see or hear about the sport of cricket, I build model simulations based on my experiences of baseball.

In his example, Gee writes that he uses his experiences of baseball in order to try to understand a sport that appears to be similar. But what are these experiences of baseball he's referring to? I would argue that these experiences consist of understanding performances. They are the memories of previous experiences of understanding performances that were developed through actions like hitting a ball with a bat, and having to respond to various outcomes of where the ball might go. These understanding performances could be thought to be compiled into an inner

schema, which is then drawn upon during the engagement in new understanding performances.

I am drawing heavily here on Perkins' definition of an understanding performance. He states (1998, p. 42):

> To understand a topic means no more or less than to be able to perform flexibly with the topic—to explain, justify, extrapolate, relate, and apply in ways that go beyond knowledge and routine skill. Understanding is a matter of being able to think and act flexibly with what you know. The flexible performance capability *is* the understanding.

To Perkins, there is an important distinction between drawing from an existing internal framework of understanding, like a mental model, in order to produce a performance that displays that understanding, and considering the performance itself to be the the material of understanding. A counterpoint to his argument is the view of Wiggins and McTighe (2005, p. 37):

> An understanding is a mental construct, an abstraction made by the human mind to make sense of many distinct pieces of knowledge. The standard further suggests that if students *understand*, then they can provide evidence of that understanding by showing that they know and can do certain specific things.

As I have stated above, I think there is a middle ground between these two views. While we do hold internal representations and organizations of meanings, they are not set in pre-organized fashions that represent dormant understanding. Rather, they are assembled dynamically upon use, and according to the contexts in which they are presently embedded. As Gee, in discussion of weddings, states (2004, p. 45):

> However, we do not build just one wedding model simulation and store it away once and for all in our minds. No: what we do, rather, is build different simulations on the spot for different specific contexts we are in. In a given situation or conversation involving weddings, we build a model simulation that fits that context and helps us to make sense of it. Our models are specially built to help us make sense of the specific situations we are in, conversations we are having, or texts we are reading.

At the same time, in support of Wiggins and McTighe, and in general the conceptions theory view of understanding (for example, see Strike and Posner, 1985), experiences of

understanding performances themselves can be considered to be stored in internal frameworks that are fixed to some degree. Take a memory, for example. Gee's memories of baseball, his experiences from which he builds simulations, are stored. The very definition of memory involves storing things in the mind (obviously, memories shift and change over time, but that is a different matter).

These prior experiences can take multiple forms. First, they can be experiences of successful understanding performances. For example, if in a baseball game one makes a hit at bat for the first time, and runs successfully to first base, that is a performance of understanding in which the player's understanding was appropriate for the situation. They might not have gained any new understanding, but their existing understanding was reinforced, and the experience of that understanding performance possibly added to their memory. Second, they can be experiences of working on understanding. If one is still figuring out the rules of baseball, and they make a hit that looks like a foul ball or a pop fly, they have to figure out how to act accordingly in response to a specific simulation that might be new to them. This experience of uncertainty in working out an understanding is also stored. Both types of experiences can contribute to new understanding performances. As Barnes writes (Mercer & Hodgkinson, 2008, p. 4):

> There are various ways of working on understanding, appropriate for different kinds of learning. Teachers commonly ask students to talk or write in order to encourage this, but drawings and diagrams, numerical calculations, the manipulation of objects, and silent thought may also provide means of trying out new ways of understanding.

The key phrase here is "trying out new ways of understanding." This is where stored prior experiences come into play, as they are resources for trying out and incrementally improving new understandings. As a further example of working on an understanding of baseball, let's say someone is learning how to hit a pitch properly. That person may not be able to verbalize the

steps she needs to take, or understand others' instructions very well. However, let's say that in one of her attempts she hits the ball really well. There are many facets of that specific performance experience: the feeling of how she swung the bat, how she was directing her focus, her sense of timing in that moment. All of these experiences can be stored, and drawn upon in the in subsequent attempts at bat in order to increase her level of understanding, and to help her determine at a meta-cognitive level what she needs to do in order to further her understanding. While this process of creating relationships between prior experiences, and determining which ones are important to draw upon, constitutes thinking, all of these relevant artifacts—the prior experiences, the context of those experiences—can be considered the material of understanding that is necessary for us to develop and enact new understandings.

Like thinking, I have defined understanding as a dynamic process situated within contexts. The distinction I make between the two is that understanding is, as Perkins defines it, a "flexible performance capability" (1998, p. 42**).** Understanding enables action, whereas thinking is more the process of building the meanings which make up our worlds of understanding. There is of course, much overlap. Engagement in discourse could be considered both a process of thinking and an understanding performance. The distinction is in what the product of such an event is. Within a discourse, understanding encompasses the kinds of actions a person is able to take or becoming able to take, whereas thinking is visible in the substance of the actions–which meanings are being built and emphasized–and the manipulation of that substance.

Rather than existing as internal representations that can be displayed from time to time, understandings are only built and manifested through situated actions, or performances. Experiences of these understandings, however, can be stored in the mind and body and drawn upon in the future, and contribute especially as aids or obstacles to developing understandings. These experiences also help us run, as Gee puts it, model simulations of the world.

3

LEARNING

From the previous chapter, the process of understanding could be defined as developing the ability to accomplish various actions within situated contexts. What, then, is learning, and how is it different from understanding? The distinction is significant. I will argue that learning is the gradual accumulation of understandings that build toward expertise in a domain (whether that expertise is reached is irrelevant here, what is important is the process of moving toward it). While one may be able to develop significant understandings within a short time span, learning is a long and wayward process that involves the accumulation of a great breadth of understandings, knowledge, and experiences (Rennie, Abell, & Lederman, 2007, p. 126). Rather than try to outline all elements of learning in all contexts, I will focus here on the kinds of learning which I think are foundational for developing expertise and that motivate continued engagement within a domain. I will also elaborate on informal learning environments, what they are and why they have the potential to be excellent educational environments for developing strong learning foundations.

In his book Changing Minds: Computers, Learning, and Literacy, diSessa (2001) tells a story about his childhood experiences with electronics and how they informed his study of physics in college (p. 77):

> From the outside, I looked "smart." I learned quickly and more deeply than most. When I got to college, I became famous, if not notorious, among my friends for having a superb intuitive feel for what we were learning in physics. I could guess answers and make good judgments about how things should turn out...but it was not native intelligence alone, if at all, that accounted for my success. It was a strong intuitive foundation built in electronics play.

diSessa's intelligence in physics was not an inherent quality, but rather the result of a plethora of childhood experiences involving playing with electronics. These experiences, as diSessa outlines,

contributed to a rich collection of "intuitive knowledge" about electronics. This collection is not a collection of facts, or even explicitly expressible knowledge, but rather experiences that help a person to be able to make intuitive sense of complicated ideas. A collection of domain-specific intuitive knowledge, therefore, could be considered the same thing as a collection of experiences of enacted understandings, where these understandings are specifically those that constitute the fundamental understandings of that domain. diSessa elaborates on his use of the term intuitive knowledge (p. 71):

> I mean by this term a whole host of ways of knowing that are beyond the stereotypes of knowledge we have culturally institutionalized in school and even in our common sense...The short version of one generalizable importance of my hobby is that, through it, I built up a rich and flexible intuition about electronic devices--what their mechanical properties in fabrication and their behaviors were, and how they worked.

The base of intuitive knowledge that he developed during childhood, he goes on to elaborate, was a crucial factor in his ability to understand topics presented later on in school settings. In terms of the ideas I have put forth on thinking and undersatnding, diSessa was able to understand these topics more easily than his peers because his store of intuitive knowledge helped to reduce the cognitive load that was needed in order to incorporate relevant artifacts into his thinking, therefore it took him less effort to be able to successfully build new understandings.

A foundation of intuitive knowledge is necessary for developing expertise within a domain, that is, intuitive knowledge is a necessary requisite for successful learning. Gee (2004, p. 4) states:

> The human mind works best when it can build and run simulations of experiences its owner has had...in order to understand new things and get ready for action in the world...Think about an employee role-playing a coming confrontation with a boss...Such role-playing in our minds helps us to think about what we are about to do and usually helps us to do it better. Think about how poorly such things go when you have had no prior experiences with which to build such role-playing simulations and you have to go in completely "cold."

Gee's example, role-playing a confrontation with a boss, illustrates this point. This interaction

can encompass many various understandings, such as how to take control of a conversation, how to phrase utterances in such a way that they defer blame or agency, and how to calm others down. The performance of these understandings is most powerful when they are integrated together, that is, when one is able to perform multiple understandings concurrently in the pursuit of a larger goal. An indicator of successful learning, I will claim, is this ability to integrate a multitude of understandings, which is essentially the ability to perform expertly. Here is where intuitive knowledge also comes into play. If one does not possess the intuitive knowledge underlying a complicated understanding, he may still be able to work with that understanding, and maybe even perform it, but he will not be able to perform it well or without significant mental effort, that is, not in a fluent way. Since there is a lack of intuitive knowledge, this means that the understanding is incomplete and still being worked on, that is, it is in development and still requires active thinking in order to be performed successfully.

To fluently integrate a multitude of understandings in a performance requires that there is an intuitive foundation for these understandings. As an example of this, Spolsky (2006) writes:

> Jared is a bond trader. He is always telling me about interesting deals that he did. There's this thing called an option, and there are puts, and calls, and the market steepens, so you put on steepeners, and it's all very confusing, but the weird thing is that *I know what all the words mean,* I know exactly what a put is...and in only three minutes I can figure out what should happen if you own a put and the market goes up, but I need the *full* three minutes to figure it out, and when he's telling me a more complicated story, where the puts are just the first bit, there are lots of other bits to the story, I lose track very quickly, because I'm lost in thought...until he gets out the graph paper and starts walking me through it, and my eyes glazeth over and it's very sad. Even though I understand all the little bits, I can't understand them *fast enough* to get the big picture.

Tynjälä (Tynjälä, 1999, p. 362), in summary of Bereiter and Scardamalia (1993), states, "pivotal in the development of expertise is converting formal knowledge into an expert's informal knowledge and skills." In summary of the same authors, Gee (2004, p. 65) writes, "when learners learn a new skill set/strategy, they need to practice it over and over in varied

contexts in order to make it operate at an almost unconscious routinized level. Then they are really good at it." Basically, fluency is essential to expert performances. Going back to Gee's example interaction, the employee may loosely understand the various conversational tasks necessary for a confrontational interaction, but if he does not have extensive experience performing each these tasks, that is, a strong intuitive knowledge of conversation, then he will not be able to incorporate his various understandings into a fluent performance.

This is why activities that develop intuitive knowledge are essential to the learning process. One may be able to understand to some degree the concepts that make up the corpus of a domain, but he will not be fluent in that domain unless his understandings are intuitive. Essentially, understandings are useless in the development of expertise unless they are, as Tynjälä states, converted from "formal knowledge" to "informal knowledge."

Gee discusses the concept of horizontal learning experiences, which I will call a sister concept to diSessa's concept of intuitive knowledge. A horizontal learning experience is an experience that does not necessarily further one's level of understanding (which would be called a vertical learning experience), but rather, prepares him for greater vertical success in future experiences of the same type. Gee writes (2004, p. 60):

> Horizontal experiences look like mucking around, but they are really ways of getting your feet wet, getting used to the water, and getting ready, eventually, to jump in and go swimming. They may, in one form or another, be essential to learning...

Gee also provides an anecdotes from his own experience learning to play a video game from the RTS (real-time strategy) genre (p. 60):

> I had liked *WarCraft III*...Though I had had limited success with the game, I had had some small success that made me feel that at another time and place, perhaps, I would do better...*WarCraft III*, it turned out - though I realized this fully only when I started *RoN* [Rise of Nations] - had *prepared me for future learning (Bransford and Schwartz 1999)* of RTS games. When I started *RoN*, I realized that I already knew something - somewhat more than I had thought. I felt I had a small foot up.

The point I want to make about horizontal learning is that it implies that successful learning is, as I stated above, a wayward process. Learning experiences do not always move forward one's skills or understandings, but nonetheless they have the potential to pre-dispose a learner for greater success in the future. The process of developing intuitive knowledge is like this. It involves getting stuck, abandoning projects and revisiting them, and reaching understandings that seem to be irrelevant to any useful fluencies. But while this process may appear to be useless, or inefficient, in actuality it serves to cultivate a rich foundation of experiences and intuitive understandings, and a deep reservoir of artifacts for thinking, that cannot be acquired in any other way, and without which true expertise cannot be developed.

Driving learning

As learning is an accumulation of understandings, it necessarily takes a significant amount of time. Therefore, as a teacher or designer of educational experiences, or even a meta-cognitively reflective learner, it is important to ask the questions: what keeps learners engaged throughout this journey, and what ensures that their learning progresses in sophistication and expertise? Using diSessa's term, how do people come to engage in "committed learning?" diSessa (2001, p. 83) defines this as:

> Committed learning, in fact, is nothing more than particular relationship between a learning and a fabric of learning activities. A committed relationship entails a feeling of ownership, personal connection, and competence such that extended engagement in those activities is perceived to be a natural extension of ourselves. We value those activities; they are self-sustaining, and they feel coherent and connected.

While external factors, such as teachers and educational environments, can influence the continued pursuit of learning, they can only have influence in so much as they are able to facilitate learners in pursuing their own lines of inquiry. Ellsworth (2005, p. 54) writes:

> You cannot give someone the experience of their learning self; yet, we are

> capable of designing places that elicit profoundly moving experiences of encountering the ‘outside’ and the power which we attribute to 'masterful teaching' and to 'pedagogical masterpieces.

I will outline here a few of the factors that I think are most important for driving learning. These factors are the experience of memorable learning events, the experience of challenge suitable for one’s level of competence, and cultural/identity based motivations. There are many other equally important factors that I will not address here, such as interest in a subject or vernacular.

The first factor, memorable learning events, has to do with the kinds of learning experiences that happen infrequently, but are of a breakthrough quality. They are significant because they give learners a sense of accomplishment, of wonder, and of ignited curiosity. diSessa (2001, pp. 104-5) terms these experiences as “rare events.” Duckworth (1987, p. 1) calls them “wonderful ideas,” and considers them to be the “essence of intellectual development.” Conventionally, they may be known as “aha moments.”

For Duckworth, a wonderful idea is a breakthrough in learning, perhaps a realization about a phenomenon or a successful experiment, that is the result of a culmination of understandings and persistent effort, such as after much struggle, finally understanding density, or being able to make a correct prediction about a phenomenon that initially seemed impossible to do. Put more simply, it is when learners have success engaging in “finding out something for themselves through their own investigations of everyday phenomena” (Duckworth, 1986).

Duckworth’s concept of wonderful ideas speaks to how I have defined learning in this chapter. Duckworth states (1987, p. 6), “wonderful ideas do not spring out of nothing. They build on a foundation of other ideas.” Within the frame of my own ideas about understanding and learning, the event of having a wonderful idea is when a learner is suddenly able to integrate the knowledge and understandings he has been forming in order to create an expert performance. A wonderful idea is, essentially, a culmination of understandings in development. Without this

experience of coming-together, it is extremely difficult for learners to feel like they are making progress, or be internally motivated to continue their inquiry. Providing these experiences should be the best thing that educators hope to achieve, as it serves to create people who engage in life-long pursuits of learning. Duckworth writes (1987, p. 8):

> Certainly the material world is too diverse and too complex for a child to become familiar with all of it in the course of an elementary school career. The best one can do is to make such knowledge, such familiarity, seem interesting and accessible to the child. That is, one can familiarize children with a few phenomena in such a way as to catch their interest, to let them raise and answer their own questions, to let them realize that their ideas are significant--so that they have the interest, the ability, and the self-confidence to go on by themselves.

diSessa's concept of rare events is in the same vein as Duckworth's concept of wonderful ideas. He states (2001, p. 104):

> ...all children deserve to have some educational experiences that are coherent with their deepest personal interests and competencies. Indeed, all of us deserve to have our educationally relevant interests fostered and to have them nested in activities that fit into a larger fabric of long-term commitment. Everyone should experience committed learning.

An important point that diSessa makes is that rare ideas are exactly that, rare. They cannot be explicitly scheduled for in a curriculum. Their content is unpredictable. Nevertheless, they are extremely important. In essence, they are "idiosyncratic" (p. 104):

> Some people will just dismiss an idiosyncratic activity as educationally irrelevant--"it just couldn't happen again"--but dismissal won't do. Idiosyncratic activities should have special relevance for education because personal ownership and fit with a child's life bring great power to learning. One of the main reasons literacies that support invention and creation--not just absorption--are so important is that they give children a toehold for their own initiative. Pretending that we can survive educationally without making room for idiosyncrasy is bound to fail to achieve anything more than boring (to us and to students) mediocracy.

Indeed, learning as it occurs is a nebulous process, full of idiosyncrasies, speed bumps, and even randomness. This is a challenge for the more rigid schedules of traditional schooling. Ellsworth (2005, p. 120) describes this issue:

> The qualitative change that is learning goes undetected by curriculums,

> outcomes, and scripted teaching strategies when they are used to "track" movements from one grid position to the next along fixed routes such as memorization, ventriloquism, citation, and repetition. Pedagogy practiced for the sake of the grid functions as a mere connector between predetermined meanings and identities. It does nothing to address the learning self in motion as it moves between the grid's binary poles and is no longer identifiable with or addressable through socially constructed positions. The learning self when it is in the making no longer coincides with whatever previously constructed knowledge about the learning we might hold.

As it so happens, informal learning contexts are excellent environments for encouraging and enabling memorable learning events to happen, and for avoiding the issue of moving learners along a "grid position." I will elaborate on this further on in this chapter.

The second important factor for driving learning is a sense of challenge, and its relation to learners' levels of competence. Gee (2004, p. 71), in a discussion of learning within video games, states:

> There is one crucial learning principle that all good games incorporate that recognizes that people draw deep pleasure from learning and that such learning keeps people playing. Good games allow players to operate within, but at the outer edge of, their competence...This feeling of the game being highly challenging, but ultimately doable, gives rise to a feeling of pleasurable frustration, one of the great joys of both deep learning and good gaming.

This is one of the reasons why video games can be so engaging. They present challenges to the player that are just out of reach, so that the game never feels too easy, but it also never feels too hard. There is a deep satisfaction to be had in overcoming these challenges, and the pleasure of that satisfaction drives further engagement. Not only that, but in overcoming challenges, the player is improving their own skills, such that subsequent problems present challenges that require progressively higher levels of competence, giving the player a rewarding sense of their own development.

Granted, not all games do this successfully for everyone (whether due to poor game design or the targeting of niche audiences), but it is a common and observable pattern. Gee

(2004, p. 71) also makes the point that good games do not present challenges all of the time, but rather cycle between challenge, and giving the player an opportunity to hone the new skills they have developed from previous challenges: “The times where players are consolidating their skills to the point of routine and taken-for-granted application give rise to another form of pleasure, the pleasure of mastery. Games cycle through periods of pleasurable frustration and routine mastery - a cycle of storm and calm.” All this talk of pleasurable experiences alludes to an important concept. Learning is fun, and playful. To be having fun, and to play, is to be fully engaged in an activity, and to have the desire to engage in that activity for its own sake. As Gee states (p. 71), “when learning stops, fun stops, and playing [engagement] eventually stops. For humans, real learning is always associated with pleasure and is ultimately a form of play.” Experiences with these characteristics are the kinds of experiences that drive continued engagement, or “committed learning.”

diSessa (2001, p. 84) states,“committed learning almost always happens in...the regime of competence.” A regime of competence is the wealth of resources that a learner holds in terms of their intuitive knowledge. It determines what one is able to learn. If learners need to acquire a skill or strategy in order to overcome a challenge in a video game, they build this skill from their existing understandings and capabilities. We do not get our wonderful ideas out of thin air, but rather come to them by means of using the understandings and intuitive knowledge we already possess.

This emphasizes importance of the kinds of learning experiences that work toward building intuitive knowledge bases, rather than conveying explicit facts or high level topics. Without the underlying base, complicated facts and concepts cannot be understood or employed in expert performances. From diSessa’s own experience, he writes (p. 84):

> My intuitive physics established a regime of competence that eventually

> included learning school physics. Had I not had the experiences that developed my intuition, trying to learn physics would have been unpleasant and most likely unsuccessful. Instead, I was lucky enough to build outward from an existing regime of competence, pursuing my hobby and gradually accumulating resources that eventually unfolded learning "formal" physics.

Trying to learn outside of one's regime of competence is not likely to result in a feeling of commitment toward that learning.

The ability to overcome challenges is dependent on the relation of those challenges to one's regime of competence, and in turn, the nature of those experiences are significant in the kinds of identities people build for themselves as learners. This is the third driving factor of learning I will discuss, that one's sense of identity in relation to specific content, contexts, and even the act of learning itself can hinder or encourage engagement, and that both educational and cultural experiences shape the development of this identity.

An important fact underlying learner identity is that learning always occurs within a cultural context, and this cultural context has a heavy impact on learning. Among many things, it can dictate what kinds of people (gender, race, age, etc.) are considered able to learn certain things (Steele, 1997, Corneliussen, 2004), and it shapes the epistemological views of learners and educational authority figures (parents, teachers, policy-makers)(Schommer, 1994)(Bell, Lewenstein, Shouse, & Feder, 2009), therefore influencing what kinds of knowledge are valued and pursued, and what methods of learning and discovery are viewed as fruitful efforts and should receive investment.

Cultural contexts can also provide excellent platforms for motivating learners, and scaffolding their progress. Gee outlines the elements of a cultural learning context (2004, p. 12):

> The process involves "masters"...creating an environment rich in support for learners. Learners observe masters at work. Masters model behavior...accompanied by talk that helps learners know what to pay attention to. Leaners collaborate in their initial efforts with the masters, who do most of the work and scaffold the learners' efforts...finally, learners are aware that masters have a certain socially significant identity...that they wish to acquire

> as part and parcel of membership in a larger cultural group.

Would not the wish to acquire a "socially significant identity" be in itself an significant motivating factor in the service of committed learning? For example, why would anyone suffer through a decade of medical school? It's obviously because they want to become a doctor. The wish to achieve a desired identity is one example of how identity can drive learning.

On a more basic level, though, a learner's identity affects how they feel throughout the learning process, what experiences they are open to, what kinds of knowledge resonates with them, and what directions of exploration they head toward. Ellsworth (2005, p. 16) describes this experience as the collision between one's internal sense of self, realm of knowledge, and way of thinking, and the "unknown ways of thinking" of the outer world:

> The look on a child's face as she experiences learning in this sense -- as the sensing of new and previously unthought or unfelt senses of self, others, and the world in their process of emergence -- might now be a media convention, but that has made it no less momentous and no less enigmatic. It is the look of someone who is in the process of losing something of who she thought she was. Upon encountering something outside herself and her own ways of thinking, she is giving up thoughts she previously held as known, and as a consequence, she is parting with a bit of her known self.

Learning is in many instances a transformation of self; the growth of our identities is shaped significantly by our learning experiences. To be a committed learner is also to be a seeker and instigator of personal transformation, whether that transformation is the coming-into of new identities such as being a doctor or being someone who is a quick-study, the shedding of old identities, such as being a novice, or the assimilation of new and unexpected perspectives and ways of being.

I mentioned Gee's claim above that all deep learning is pleasurable. I argue that it is pleasurable not only because of the exhilarating experience of having breakthroughs, or the joy of diving into a passion or itching interest, but also precisely because true learning involves personal growth, and the rewarding feeling that comes with knowing one has grown as a result of

their efforts. The pursuit of self-improvement goes hand in hand with the pursuit of learning.

4

LEARNING AND UNDERSTANDING IN INFORMAL LEARNING ENVIRONMENTS

I have argued that intuitive knowledge bases and intrinsic motivations toward learning are necessary elements of any successful, long-term learning endeavor. Here I will make my case for why informal learning environments are well-equipped to foster these two things. Informal learning contexts encompass a broad range of environments, and I will limit my use of the term to refer to "designed learning environments" (Bell et al., 2009, p. 127), specifically institutional settings such as museums, libraries, and even community learning spaces such as DIY biology labs[1] and hackerspaces[2], as opposed to environments for "everyday learning" (p. 95-96), such as the family dinner table. There is a large amount of research on the value of informal learning environments for learning in specific content areas, especially in science (for an extensive bibliography, see Bell et al., 2009), but I will focus here on how informal learning environments serve the aspects of learning which I have just discussed, namely the development intuitive knowledge and the fostering of committed learners.

Some informal learning institutions, such as museums, have concrete learning missions, and others, such as DIY bio labs and hackerspaces, are better considered to be domain specific learning communities (this discussion will primarily focus on learning in museums, especially science museums). The main difference between these places is that museums and other similar institutions take a driving role as creators and providers of experiences, while community-driven

1 A DIY biology lab, or community biology lab, is a laboratory open to supporting members and/or the general public, which supports the learning and exploration of biological topics outside of an academic or industrial context, and which provides access to infrastructure that is normally hard to find outside of professional laboratories.

2 A hackerspace is a community-run space, open to supporting members and/or the general public, that supports collaboration and exploration of digital technologies.

institutions let their participants and members fill this role. This can be seen through the commonly used terms “visitor” and “member.” The museum learning environment is designed by the institution itself, and while it may choose designs that treat visitors as “co-creators” (Simon, 2010, p. 271), the relationship that exists is still primarily one of the museum as server and the visitor as receiver. Community driven institutions such as hackerspaces are the opposite. Users of the space are not thought of as visitors so much, but rather as “members,” and are given privileges that a term like that suggests. As such, initiatives in these community driven institutions tend to be very grassroots oriented, while museum-based initiatives are much more top-down oriented.

With these distinctions in mind, both museums and community-driven institutions share two important characteristics which I will use to help define my use of the term *informal learning environment*:

1. Informal learning environments are not prescriptive in the knowledge they convey and the understandings they promote. Learners are able, and encouraged, to discover diverse meanings from their experiences in informal environments. These discoveries may be guided toward one direction or another, but a strict uniformity of understanding is not enforced or even desired for learners.
2. Informal learning environments place authority and agency in learners. Learners are in command of how they spend their time, where they place their attention, and what actions they take. There may be suggestions about what activities to engage in, and what content to focus on, but control over the act of learning itself is yielded completely to learners.

Informal learning environments are not prescriptive in the knowledge they convey and the

understandings they promote

As I have previously conveyed, developing intuitive knowledge is a messy process. It is wayward, full of abandoned paths and revisited paths, diverse and seemingly irrelevant experiences, non-predictable, and idiosyncratic. Prescribing a specific path that learners must take in order to supposedly reach some learning goal is a great way to distract from and stunt the development of an intuitive knowledge base that is needed in order to truly attain mastery of a domain. Additionally, it serves to isolate and discourage learners who may not prefer or be used to the approach being prescribed. In regards to science learning specifically, Bell et al. state (2009, p. 40):

> Many children who fail in school, including those who are from non-dominant cultural or lower socioeconomic groups, may show competence on the same subject matter in out-of-school contexts (McLaughlin, Irby, and Langman, 2001)...Freedom from a timetable that dictates a schedule for learning, for example, may allow children to explore scientific phenomena in ways that are personally more comfortable and intellectually more engaging than they would be in school.

Informal learning institutions go about avoiding prescriptive learning in very clever ways. One such example is the Exploratorium in San Francisco, one of the first interactive science museums in America and a pioneering supporter of research into informal learning. The museum floor of the Exploratorium is riddled with exhibits, which mostly demonstrate physics phenomena. However, it is rare to find an exhibit that is accompanied by much text. When there is text, it very rarely prescribes a specific way to use the exhibit. This is important, because not only do these exhibits avoid dictating to a learner what they should do with them, they also tend to avoid letting learners easily fall into ruts of engagement, where they follow the easiest or most obvious way of engaging with an exhibit and walk away having had a shallow learning experience. Frank Oppenheimer, the founder of the Exploratorium, describes one of his favorite exhibits, a drawing table and pendulum (1976, p. 3):

> People use this exhibit in many different ways...it is an exhibit for everybody...visitors can find systematic things to do with it with relative ease; and one can obviously invent activities that are "out of context," clearly not part of any preconceived syllabus.

Essentially, the exhibits are open ended enough to enable play, yet very cleverly designed to showcase certain phenomena. Thus, while the activities of play themselves are not dictated, they tend to reside roughly within a content area, that of the phenomena demonstrated by the exhibit.

A profound example of this comes from one of my own experiences at the Exploratorium, playing with an exhibit titled The Bernoulli Levitator (Exploratorium, n.d.). The Bernoulli Levitator, decoration aside, consists essentially of a large, heavy wooden disk, and a wide tube that blasts air downwards onto it. Lifting the disk is difficult because of its weight and the strong force of air blowing into it (although two children would still be able to do it), but if one lifts the disk high and close enough to the tube, it will float in mid-air as if stuck to the tube. It behaves this way because fast moving air has a lower atmospheric pressure. Basically, air is constantly exerting pressure on its surroundings. In order to understand this phenomenon, it helps to realize that air behaves like a fluid. When there is a lower concentration of air in a certain area (therefore, a lesser atmospheric pressure), higher concentrations of air surrounding that area will flow into it with force, similar to the way water in a tub flows to fill the void that is created when you immediately step out of it. The force exerted by air (atmospheric pressure) is quite strong, at 14.7 pounds per square inch, and useful for a myriad of tasks such as pumping well water, running car engines, and even breathing. In the exhibit, the fast moving air, or the air with the lowered atmospheric pressure, is located above the wooden disk. This means that there is more force being exerted on the bottom of the disk than on the top, therefore causing it to be lifted.

This is a difficult concept to understand, and I was not able to understand it immediately after playing with the Bernoulli Levitator. However, years later, this experience was essential for

me in reaching an understanding of atmospheric pressure and Bernoulli's Principle. Along with other experiences like trapping liquid in a straw, it contributed to my building of an "intuitive knowledge ecology" (diSessa, 2008, p. 45), that served as a resource for understanding atmospheric pressure. Why did this work? I have distinct memories of playing with the Bernoulli Levitator. I remember what it felt like when the blowing air transitioned from pushing the disk downward to causing it to be pushed upward, and I remember what it felt like for the upward pressure to strengthen again when I moved the disk to the side so that it stopped covering the tube completely. Essentially, I have a personal experience of what air pressure feels like. This kind of experience may be useful to others, it may not. The point is that people will walk away with diverse and idiosyncratic experiences from interacting with this exhibit, and that these experiences have a greater potential to be useful aids for future understanding than uniformly prescribed experiences, such as a required school lab on air pressure. Since I was the sole determinant of how I interacted with the exhibit, I was more engaged and rapt in my activity than if I had been required to do specific things with it. The experience remained significant to me and I did not forget about it.

Another reason that non-prescribed paths of learning are important is that they foster an individualized experience of discovery, which helps create committed learners. Oppenheimer uses the term addicts in this way (1976):

> The remarkable feature of the process of individual discovery, whether of detail or of generality, is that the first taste of success can be addicting. For some obscure reason we, as teachers, are committed to turning on addicts. But potential addicts are not programmable; one never knows who they are or when they are vulnerable. We argue among ourselves: if we do not tell people what they are supposed to find, many will leave with a sense of frustration, but a few will have become addicted to finding more than anybody knew was there.

We may one day be able to predict which approaches or experiences are the most effective for different individuals and their learning, but we are nowhere close to having that capability today.

It is a more reliable strategy to accept that what constitutes a meaningful learning experience is different for everybody, and work with it. Well-designed informal learning environments adopt this strategy. As a learning institution, to have the goal that every learner will become an addict in a narrow content area is unrealistic and naïve. Different things drive different people. Museums like the Exploratorium do not claim or try to reach everybody, but rather they open their doors to learners who are willing and enable them to continue on stronger, and perhaps they inspire a few passersby as well. In the world of education, the emphasis should be not on making everybody an addict of specific content areas we find important, but rather ensuring that everyone has the chance to experience being an addict of discovery at something, no matter what that something is.

The unpredictability of the informal learning experience is yet another characteristic that sets it apart from formal learning experiences, and serves to imbue learners with memorable experiences that empower them as learners. Instead of trying to predict which experiences will be most valuable to learners and provide them, well-designed informal learning environments create an atmosphere which promotes frequent discovery. Ellsworth (2005, p. 45) argues that pedagogical designs of this nature "must create for us a relationship to..the world...in a way that keeps the future of what we make of that relation and what we might think there open and undecided." In light of this imperative, she states (p. 54), "this would make it impossible for...[a] teacher to anticipate what form a learning will take or how it will be used. It would also make it impossible to conjure a learning." In other words, creating space for learning to happen in unanticipated ways has the effect of allowing for and causing deeply meaningful learning experiences to occur. As Bell et al. state (2009, p. 56):

> It may well be that contingency, insofar as it allows for spontaneous alignment of personal goals and motivations to situational resources, lies at the heart of some of the most powerful learning effects in the informal

> domain.

Following an undecided learning path is not much different from play, which, as Gee argues, is essentially what all meaningful learning really boils down to.

Informal learning environments place authority and agency in learners

Perhaps the most significant difference between informal and formal learning environments (mainly, traditional schooling) is in the placement of authority. Authority in school settings generally brings to mind thoughts such as a teacher's ability to govern the behavior of students and to make impactful evaluations of their performance, or of a school's ability to define a student's daily schedule and mandate that they adhere to that schedule. While these privileges bring up many issues, meaningful learning can happily occur in spite of them. Where school based authority has the potential to be much more harmful to meaningful learning, however, is in its command of attention. For example, students are often made to focus on a given topic depending on the class, or at least, they are made to keep any lack of focus silent or shortened, in order to not disrupt the flow of the class. In fact, there are entire chapters written about teacher techniques for managing classroom distractions and keeping students on course (Kennedy, 2009, p. 95). Alternatively, informal learning environments do not aim to force the attention of the learner, but rather to attract it. Allen (2004, p. 18) writes:

> On the exhibit floor there is no accountability, no curriculum, no teachers to enforce concentration, no experienced guide to interpret and give significance to the vast amounts of stimulus and information presented. Without restrictions, visitors have complete freedom to follow their interests and impulses as they move through a public space packed with exhibits all vying for attention. This quality of totally unrestricted choice in what to attend to has huge implications for learning in the museum setting.

It might seem that a lack of guidance of attention can only inhibit the learning process, distracting learners from ever spending a long enough amount of time in one place in order to

develop understandings. On the contrary, the strategy of making learners place their attention in a specific area ignores the most important factor of committed learning: interest. Mandating the focus of a learner to one content area, i.e. prescribing a learning path, only serves to prevent that learner from moving toward discovering the content areas that truly capture them. And if the learner is already captivated by the prescribed content area, then focus need not be mandated anyways. As Carr writes (Carr, 2006, p. 14), "[w]herever attention is under individual control it cannot be easily seized by an authority; in museums and libraries, our awareness of complexity cannot be diluted by formal, acontextual, reductive classroom discourse." By allowing learners to skip from one place to the next acknowledges that attention is a limited resource, and that it is best spent in areas that are relevant to one's interests.

I do not mean to argue against the importance of the facilitation of learning by figures such as teachers or masters in a master/apprentice relationship, but rather certain, over-prescriptive forms of teaching that are prevalent in the educational world today. And while the facilitation of learning by figures such as teachers is an important element of the learning process, the ability to self-facilitate one's learning is of equal importance, though not often acknowledged in the literature until recently. It has been shown that learners in museum contexts possess the ability to self-reflect on their learning experiences, and actively engage in this reflection during their engagement with exhibits (Bell et al., 2009, pp. 147-8). Additionally, utilization of metacognitive strategies is an important characteristic of domain experts, and the development of expertise (Sternberg, 1998, pp. 133-4). Informal environments present numerous opportunities for the practice of metacognition and self-reflection, partly because of the absence of a facilitator who directs what the learner should think about, and partly because these environments prompt metacognitive thinking as a way of resolving mental conflicts.

Another way that informal environments effectively avoid assuming authority is by not

taking on the role of evaluator. Bell et al. (2009, p. 56) conveys this eloquently:

> The very premise of engaging learners in activities largely for the purposes of promoting future learning experiences beyond the immediate environment runs counter to the prevalent model of assessing learning on the basis of a well-defined educational treatment (e.g., the lesson, the unit, the year's math curriculum). In addition, many informal learning spaces, by definition, provide participants with a leisure experience, making it essential that the experience conforms to expectations and that events in the setting do not threaten self-esteem or feel unduly critical or controlling—factors that can thwart both participation and learning.

While informal learning environments do have specific learning goals, and take evaluative measures to assess their performance in meeting those goals, these goals are not necessarily made explicit to learners, additionally learners are not given the burden of trying to meet these goals, and they experience no ill personal effects if they fail to meet them, or happen find value in their experience that does not conform to the prioritized values of the learning initiative. In contrast to situations in which learners are required to meet the performance criteria of an authority figure, the learners instead becomes the evaluators, their performance criteria for the informal learning environment relating to how satisfied they were with their experience.

I have outlined several essential characteristics of successful learning, and elaborated on how designed informal environments are well-equipped to provide meaningful learning experiences of such nature. In the next section, I will discuss strategies and general principles to consider when designing informal learning environments.

5

DESIGNING INFORMAL LEARNING ENVIRONMENTS

Designing an informal learning environment that is both successful in terms of the learning experiences it provides, and in the diversity of learners it is able to provide those experiences to, is a difficult challenge. Unlike a teacher in a traditional, classroom-based lesson, the designer of an informal environment does not have the ability to react on-demand to the behavior of learners. However, an advantage of informal learning environments is that learners have a much greater affordance to shape their experience in a way that is pleasurable and relevant to them. Learners react on-demand, in individualized ways, to their own shifting desires and interests. The approach to designing such environments differs in many ways to a traditional, curriculum-based approach to designing a lesson or series of lessons.

Science museum environments have the powerful ability to not only promote play and self-driven inquiry, but to guide it implicitly. It is extremely important that a designer of such experiences be aware of this strength, and utilize it. While engagement in play is an efficient learning state in terms of the development of intuitive knowledge (diSessa, 2001, p. 98), it can be difficult for educators in formal learning environments to accommodate or harness it in their lessons. Informal institutions are well suited to achieve this. First, they are culturally regarded as providers of leisure experiences (Allen, 2004). This relaxes expectations associated with formal, teaching-oriented learning environments, and may serve to increase engagement (Hohenstein, 2006, p. 1). Second, although the museum environment gives visitors full agency over their activities and attention, it can also be designed in such a way as to attract visitors into specific domains of engagement, for example play involving experimentation with air pressure. That is to

say, a carefully designed museum environment will be able to induce play within desired content areas, while not robbing its visitors of agency. Additionally, it will be able to promote engagement in modes of thinking deemed necessary for acquiring certain understandings. The designer of an informal learning environment is, therefore, a provider of the kind of experiences that Gee (2004, p. 52) argues help us run simulations of world. It is in the course of this play and engagement that intuitive knowledge seems most likely to be developed. By play I specifically mean "investigatory" play, as opposed to "fantasy" forms of play (Bell et al., 2009, p. 138), in which the focus of play is on exploring the actual behaviors and capabilities of the environment, rather than any potential imaginative uses of the environment.

Three principle qualities of designed environments

Some factors to think about when designing for these outcomes are the appeal of activities and objects within the environment, their ability to disequilibrate learners, and their ability to draw relevance to learner's lives. These factors, respectively, enable educational designs to be interesting, to drive inquiry, and to have educational impact, which in turn promote self-discovery and the development of intuitive knowledge. The first factor, appeal, is a driver of interest. It draws the museum visitor into engagement within the content area addressed by the activity or object, and creates an opportunity for continued engagement. It rests on the designer to compel visitors to become interested, and the necessity of capturing interest is a constant, that is to say, the entire process of engagement must be interesting, not merely the beginning and end. Allen (2004, p. S18) writes of the museum experience, "it is not enough that an exhibit has a culminating point or experience that is rewarding to visitors; *every intermediate step* in the visitors' experience must be sufficiently motivating that they make the choice of continuing to invest time and attention there."

Museums and other informal learning institutions serve a diverse public. In order to design for maximal inclusiveness and appeal, and so that "every intermediate step" is motivating, a designer must utilize numerous media modalities, appeal to multiple senses, and accommodate diverse modes of exploration. By providing this diversity, the design not only increases its broad appeal, but also accounts for multiple points of entry, contingent paths of inquiry, and "different modalities in meaning making." (Kalantzis, Cope, & Cloonan, 2012, p. 74). This practice of diversifying an educational design stems from Kalantzis, Cope, and Cloonan's concept of a pedagogy of multiliteracies (p. 74):

> A pedagogy of multiliteracies allows alternative starting points for learning (what the learner perceive to be worth learning, what engages the particularities of their identity). It allows for alternative forms of engagement (the varied experiences that need to be brought to bear on the learning, the different conceptual bents of learners, the different analytical perspectives the learner may have on the nature of cause, effect, and human interest, and the different settings in which they may apply or enact their knowledge). It allows for different learning orientations (e.g., preferences for particular emphases in knowledge making and patterns of engagement). It allows for different modalities in meaning making, embracing alternative expressive potentials for different learners, and promoting synesthesia as a learning strategy.

One facet I will add to this is the important role that emotional and sensory appeal plays in engaging learners with content (Bell et al., 2009, p. 127).

The second factor, designing for disequilibration, is a way of creating challenges that a learner must overcome, and also serves as a tactic for helping learners develop understandings. By disequilibration I mean Piaget's concept of a disequilibrating state between one's internal world and the external world (Allen, 2004, p. S18), where the behavior of phenomena in the external world does not match the expectations that one has for those phenomena. For example, in the case of my experience with the Bernoulli Levitator, I experienced disequilibration upon seeing a heavy wooden disk be able to float in the air. That sense of disequilibration compelled me to engage with and investigate the exhibit, and the only way I had to resolve that feeling of

tension was to strive toward building new meanings and developing new understandings that allowed me to make sense of the phenomena I was being exposed to.

As Carr (2006, p. 10) writes, "Museums and libraries create problems for which the only solution is critical thinking." It is in the careful design of disequilibrating problems that a designer can find the opportunity to guide the engagement of learners with some predictability. This can be thought of as shaping a line of inquiry. Inquiry, as I will define it, is the use of various modes of thinking in pursuit of developing understandings that resolve conflicts of disequilibration. So not only does a design aim to lead learners toward developing understandings, but it also aims to help learners gain experience with the modes of thinking necessary for those understandings.

It is within the context of inquiry that we are able to have self discoveries—wonderful ideas—of a meaningful nature. This disequilibrating problem approach enables a designer to be able to steer learners toward developing certain understandings, without necessarily dictating terms of engagement or usurping agency. That is to say, it does not matter how an understanding is reached, only that that understanding helps resolve disequilibration. Additionally, when an activity is not mediated by an educational authority, but rather by self-driven inquiry, discoveries made within the context of that activity can perhaps be truly felt as self-discoveries. Further, in the absence of explicit evaluative expectations, a failure to make discoveries may be less discouraging.

The third factor, designing for relevance, is important for inspiring learning that goes beyond the immediate interaction, for justifying the effort given to the interaction, and for ensuring the impact of an informal lesson is long-lasting. Designing for relevance acknowledges that learning works best when it is situated within a cultural context. Therefore, a designer must acknowledge the cultural connections that they want visitors to make with content, and also what

cultural identities learners might associate or ascribe to that content. As an example, consider the difference between an exhibit on anatomy that emphasizes the history of scientific discovery, versus one that emphasizes the knowledge necessary for being a doctor. In these two cases, the cultural connections that are being made with the exhibit convey very different meanings for what the exhibit is about and what value it contains.

Designs that go beyond intuitive knowledge

I have discussed designing for the more implicit aspects of learning, interest and intuitive knowledge. While the greatest strength of informal learning is its ability to provide a strong foundation for intuitive knowledge and motivation, achieving an understanding of concepts that stretch beyond the realm of intuitive knowledge is still an important outcome that should be included in the design of informal learning environments. From an epistemological standpoint, the development of these kinds of sophisticated understandings is important simply because it is visible, and arguably the most culturally valued form of learning. Providing learners with concrete sophisticated understandings is necessary in order for informal learning institutions to justify their positions as educational resources. From a committed learning standpoint, and referring back to my discussion of video games in chapter 3, it is important to provide learners with understandings that they can use in practice. This provides them with the pleasurable sense of mastery, and enables them to further engage with that area of content.

A consideration of the scope of understandings is important, because museums only have access to learners for very limited amounts of time. I will note that in other informal environments, especially hackerspaces, extended learner engagement is much more common, and the design approach should be treated differently (for example, a design of a hackerspace will prioritize community development and empowerment to a greater degree than a museum). It

is simply not possible in a museum, depending on a learner's existing level of knowledge and understanding, to develop certain understandings that would normally require weeks or months of classroom time. This necessitates that a designer identify what concepts are within their reach given the limits of the environment. These should be the concepts of a domain that serve as the bedrock of all subsequent concepts, and that are most rooted in our intuitive understandings of the world, i.e. that lend themselves well to design. For example, diSessa (diSessa, 2001, p. 72) talks about his experience understanding the complex concept from electromagnetic theory called *hysteresis*, which has to do with driving and realigning the magnetism of magnetic materials. This is not an ideal concept to treat in an informal environment. However, diSessa notes that he was able to understand this concept much more easily than his peers because of the intuitive knowledge he developed building radios as a child. He was able to relate the concept of hysteresis to the more primitive experience of turning a radio knob in order to get a clean signal.

For an informal learning environment to provide the underpinnings for understanding a concept like hysteresis, it must provide the opportunity to develop intuitive knowledge, like diSessa's experience with radio knobs. It must also provide the opportunity to internalize the ways of thinking that are most useful for developing that understanding, and finally, it must provide opportunities to develop and practice the fundamental understanding performances that lead to higher level understandings.

In the case of hysteresis, this means creating simple opportunities for which to develop understandings about electricity, magnetism, and perhaps even the wave-like behavior of particles, all much simpler concepts that have direct connections to our intuitive knowledge bases. For example, electricity and water share many behavioral properties, almost every potential visitor will have used magnets and electronic devices in his lifetime, and the concept of a wave is also easy to grasp and rooted in early experiences of water. These are all valuable

resources that make lower level concepts such as circuits and magnetic polarity easier to understand. In terms of promoting a way of thinking, this could possibly be borne out in the type of questions and suggestions included in textual objects present in the environment, or more indirectly by creating activities that are performed in proximity to other visitors working on the same activity. In this way, learners are able to observe and pick up new ways of thinking and doing, through talk and observation, from the other people around them. Finally, making the possible uses and ways of interacting with an exhibit or activity as open ended and engaging as possible goes a long way toward ensuring that learners are able to continuously explore within the environment in ways that leverage and strengthen developing understandings, without their experience getting boring or stale.

Low level concepts are necessary precursors to the understanding of higher level concepts. However, oftentimes these lower level concepts are never really fully understood by learners, even in the context of extensive formal learning experience (Bracey, 1998). As a result, learning of a greater level of sophistication is forever stifled until the fundamental concepts become truly understood. Informal learning environments should prioritize the authentic development of fundamental understandings.

Learning is an accumulation of understandings, and designers must acknowledge that they can only give learners a certain limited degree of new understanding. This does not understate the importance of imparting these understandings, but rather emphasizes the fact that no single actor can provide the full breadth of meaningful learning for a learner, and that every agent that contributes a piece of understanding is important. And any agent that succeeds in providing the motivation that drives a learner to continue the pursuit of learning within a domain should be considered to have made a paramount educational contribution.

Design principles

Elements of an informal learning environment can be thought of as belonging to two families. There are some aspects of an environment which are in the family of content, or educational material, and other aspects of the environment that can instead be considered to perform tasks that support engagement with content. For example, a knob that controls the frequency of a soundwave is a supporting element, while the soundwave itself is the content. The more invisible, or seamless, the design of supporting elements is, the more easily learners will be able to engage with content. In this case, the level of invisibility has to do with the amount of thinking, or mental effort, a learner has to spend in order to make use of the supporting element. If using an element comes naturally without any thought, it can be said to be invisible. When said knob is hard to find, or when there are no indicators that it is necessary to manipulate it, the amount of effort and time a learner has to spend before even engaging with content is increased.

One approach to designing for low barriers of engagement is called "user-centered design." Allen (2004, p. S21) defines this as an approach that "promotes the creation of objects that, by virtue of their physical forms and locations, invite certain kinds of use and not others. Such design often goes unseen and unappreciated because, ironically, masterful design results in objects that seem obvious and simple to use." While Allen specifically refers to the design of museum exhibits and other physical objects, the philosophy of this approach can be applied to the creation of spaces and learning environments in general. The quality of invisibility of designed objects has to do with how easily and quickly they are able to be used, and this can be analogized beyond object use to thinking in general. When creating an informal learning space, one can ask the questions: what are the elements of this space that are barriers to thinking; what are the obstacles that distract learners from the task of thinking. One simple example deals with the concept of museum fatigue (Hein, 2013, p. 44), namely that museum visitors, as a result of

mental and physical effort, become so fatigued that they cease engagement with the museum environment. This can happen after a short amount of time, even less than half an hour (p. 104). A simple way to resolve the problem of museum fatigue is to disperse plenty of seating throughout the museum, and to reduce the level of physical effort required to interact with exhibits. In this case, the barrier to thinking can be identified as a lack of opportunities to restore energy.

The other aspect of the user-centered design approach that can be generalized is the concept of "[inviting] certain kinds of use and not others" (Allen, 2004, p. S21). This concept can be thought of as designing environments that attract certain ways of thinking and modes of engagement. I consider this to be a crucial strength of designed informal environments: the user-centered design approach to informal education, when generalized beyond object use to thinking and learning, is a way of acknowledging and harnessing the powerful thinking and learning that occurs during investigatory play.

Informal learning institutions do not hold a monopoly on learning through play and in informal settings. We learn informally throughout our lives in all sorts of everyday situations, such as at family meals, on a walk through the park, in daily conversation, etc. Why then, do we need them, and what value do they provide that we are not already able to get in our everyday lives? I believe that it is the focus on design that sets these institutions apart from our everyday informal learning experiences and allows them to offer a valuable experience that cannot be had elsewhere. Informal institutions are valuable to learners because they provide experiences that are both enriching and leisure-based, and they are valuable to educators because they enable them to serve content and implement educational initiatives that reach broad audiences in a meaningful way. Being able to serve both of these groups of stakeholders is expected of these institutions, and represents a significant challenge. Allen (2004, p. S18) addresses the some of

the tensions and aspirations related to this challenge:

> We expect these institutions to provide a hugely diverse visiting public with entertainment, the freedom to choose their own path, follow their personal interests, do their own inquiry, and create their own meanings. Yet at the same time, we want our museums to be respected educational institutions where people can spend an hour and come away having learned some canonical science. This dilemma plays out at every grain-size, from the largest organizational tensions between market and mission to the smallest design challenges of a single exhibit element. Over the last decade I have come to believe that it is indeed possible to create exhibit environments where visitors are simultaneously in a constant state of free choice and in the process of learning some form of science. But it is difficult, and calls for a program of research that focuses on the detailed features of the physical environment in which such learning is deeply situated.

We can see that informal learning institutions, museums especially, have the potential to provide play-based experiences that align with the understanding goals of educators, in a way that allows for diverse learning contingencies, but also restricts those contingencies to be within content domains. As such, they are able to serve the best interests of both educators and learners in a balanced way. This model serves educators by providing them with a vehicle to impart desired understandings to learners, and it serves learners by excluding the coercive and over-evaluative elements of formal educational models. In the words of Bell et al. (2009, p. 128) :

> While professional educators—designers, facilitators, teachers, curators—have scientific, social, practical, or other goals for participants, these are achieved only in partnership with learners. This is particularly salient in designed spaces, where learners are not assumed to operate under strong cultural pressures to participate or achieve a particular goal, as they may be pressured to do in schools, educational programs, and workplace settings. Participants in designed science learning settings control their own learning agenda.

Assessment

The designer of an informal environment must try to anticipate and accommodate the plethora of possible interactions that might unfold between the environment and its users. Therefore, one of the most necessary aspects of design is the willingness to be iterative: constantly refining and improving aspects of the environment in response to observed interactions of users within that environment. This brings to light one of the most important principles to consider in designing informal environments: figuring out how to evaluate the

impact of one's design, and how to use assessment data to inform future designs.

Informal environments do not lend themselves to the more typical forms of assessment such as tests and project work, partly because users of informal environments are not making the level of commitment that would justify those forms of assessment, and partly because much of what is learned in informal environments not easily seen. Therefore, when assessing a design, deciding what outcomes for which to assess is very important. One may find themselves disappointed if they look only for the evidence of specific understanding performances, because they will overlook the vast number benefits that are gained outside of that criteria (Bell et al., 2009, pp. 62-3). Instead, it is important to acknowledge that in a diversity of learner outcomes, any single assessment criterion will only provide a small window into the actual impact of a design. Assessing for multiple criteria will provide a fuller picture of a design's impact, and should be done even if this may necessitate a much greater expenditure of resources.

Other than understanding performances, possible criteria to assess for include general happiness and pleasure with a museum experience, discursive references to knowledge presented in the museum environment, and frequency of return visits. Assessment research is necessarily qualitative, and some useful methodologies include discourse analysis, facial expression analysis, and self-reporting (through surveys/questionnaires and interviews) (Bell et al., 2009, pp. 59-61). With any of these methodologies, it is imperative that the research method not feel overly evaluative of participants, in the sense that they may be wrong or display an insufficient level of performance (p. 304).

6

CASE STUDY

In order to collect data on informal learning, I built a small exhibit called the Water Circuit. The Water Circuit is essentially a construction of what is called a half-adder in electronics. This simple circuit is found in computers in the millions, and is what enables them to do addition. Using some clever tricks to direct the flow of water (Berque, Serlin, & Vlahov, 2004), I built a model of the half-adder that ran on water instead of electricity.

The purpose of the exhibit was to engage learners in what is called computational thinking (Wing, 2008, p. 3717), and to illuminate, in a hopefully intuitive way, one facet of how computers work. Computational thinking is essentially an algorithmic form of thinking that is used to solve problems, and that relies heavily on abstraction of elements (p. 3717). Familiarity with this mode of thinking is important for achieving fluency with computers and digital media, and for dealing with all sorts of contemporary discipline specific problems (Fischer, 2005, p. 2).

Although I was not able to test drive the exhibit within the context of an informal institution, I made efforts to ensure that the context of the interaction was as informal as possible. This included my not interfering with, or even being present for, participants' interactions with the exhibit, and ensuring the atmosphere was non-evaluative by not offering a right or wrong way to interact with the exhibit. In most cases, I did not offer any guidance or information about the exhibit prior to the interaction. However in one case, due to time constraints, I did offer a small piece of information and a challenge to the participants. Below is a discourse analysis of transcripts taken from two different group interactions with the Water Circuit.

The Water Circuit

The circuit works by routing the flow of water to come out of different tubes, depending on which buckets the water is poured into on the top. This constitutes addition of two numbers that are either 0 or 1, so the circuit can add up to 2. If water is poured into only one of the buckets on the top, that is the equivalent of telling the circuit to compute 1 + 0. If water is poured in both buckets on the top, that is the equivalent of telling the circuit to compute 1 + 1. If the result of the computation is 1, then water will pour out of the large tube on the bottom right. If the result of the computation is 2, then water will pour out of the large tube on the bottom left.

Discourse analysis

The following two transcripts are taken from sessions in which multiple users interacted with the exhibit together. The first transcript is from a session involving two people, and the second transcript is from a session involving four people.

Excerpt 1
Two people, early 20s, participants in a research session on the exhibit

1. A: so the water will only get here
2. B: I don't know, I don't know what the situation would be in which (.) the water
3. B: would go only here though
4. A: Right no [...]
5. B: only if it, but this looks like it's made to be able to overflow
6. B: but also it doesn't
7. A: It's probably only if, only if [points to a part of the exhibit]
8. B: well
9. B: oh, ohh!
10. A: yeah
11. B: ohhhh
12. A: mhmm

This exchange takes place early on in A and B's time with the exhibit, in which they were working together to predict how water would flow into one of the buckets on the exhibit. In this excerpt, A seems to have figured out what will happen: in line 1, she makes a declarative statement. A then helps B also reach that same understanding. In line 7, she offers an illuminating hint to B. Her utterances in lines 10 and 12 can be seen as similarly reinforcing her position of understanding, while B reaches that same understanding. For most of this excerpt, B voices her difficulties in understanding how a part of the exhibit works, eventually reaching an understanding with the help of A. Achieving this understanding is powerful for B. In line 9 she exclaims her realization loudly, and then further emphasizes that realization with a long "ohhhh" in line 11.

Excerpt 2
Four people (all different from excerpt 1), early 20s, all members of a college class interacting with the exhibit in a quasi-informal context

1. C: Whereas if you just have one it'll go here and go down here, and that's how it goes through here
2. D: mhmm
3. C: Whereas if you just have, where if you have both it'll get stuck in this
4. D: Oohhh
5. E: yeahhhh, [...]
6. F: yeah it gets stuck there and it goes straight down to this one which, oh but that's just a waste
7. C: No no no no this one
8. F: yeah but how, where
9. C: This one has one in the back
10. E: Oh cuz this
11. F: okay
12. E: does it go, [...] it goes down and in versus one it goes
13. F: Oh this one comes up here, okay
14. C: Yeah, so that's when there are two, cuz you see they hit each other and just go straight down
15. F: OOhhhhhh, I get it okay. Yeah, versus, okay I see
16. C: But if you just do the one, like and it doesn't matter which one you do I guess
17. F: yeah no it shouldn't because either way it's gonna go here
18. D: Yeah okay
19. F: Yeah
20. E: goes down, that's cool

A pattern of discourse similar to Excerpt 1 occurs here. D, E, and F are all working out difficulties in understanding how the exhibit works, while C has already reached an understanding and is working to share that understanding with the rest of the group. Once this understanding is reached by the others, outbreaks of emotion occur, just like in excerpt 1. In line 15, F exclaims loudly and pronounces that she "get[s] it." Similarly, in lines 18 and 20, D and E both express understanding, with E also expressing a positive affect regarding the understanding ("that's cool").

In both excerpts we see participants expressing a positive affect as a result of reaching new understanding, in other words, they are making small discoveries. These discoveries are not quite at the culminating level of a "wonderful idea" yet, but they are nonetheless new realizations

about phenomena that provide excitement for learners. I discussed in chapter 4 the importance of creating incentives for continued investment of time and energy with an exhibit, wherein each stage of the process of engagement should be rewarding. Perhaps these small expressions of discovery found in these data are instances of such stage-wise rewarding experiences. I also discussed, in chapter 3, Gee's idea of challenge versus mastery in video games, wherein successful games alternate between providing challenges at the appropriate level, and providing space to execute the mastery acquired from previous challenges. In these data, there are instances of both. Users B, D, E, and F all experienced the challenge of understanding how a certain part of the exhibit worked. They also were all able to overcome that challenge, but not too easily, as seen by the amount of talk that had to occur before they reached understanding. This suggests that the challenge was at an appropriate level. On the other hand, both users A, and C were able to put to use understandings they had previously developed during the interaction, in the form of helping their peers reach the same understanding.

These exchanges can also be viewed through Hawkins' (1974) framing of an “I”, a “Thou”, and an “It.” This idea centers around the three pillars of an educational experience. The I and Thou are the teacher and learner, and the It represents meaningful content that drives the engagement of the former. In discussing the relationship between teacher and student, or adult and child, he states (p. 54):

> When they [children] do need it [external support] and there's no one around to contribute the adult resonance, then they're not always able to carry on the process of investigation, of inquiry and exploration, of learning, because they need help over a hump that they can't surmount through their own resources. If help isn't available, the inquiry will taper off, and that particular episode, at least, will have failed to accomplish what it otherwise might have.

While informal learning environments may not provide the traditional teacher-student relationship, we can see from this data that nonetheless they do enable the kind of scaffolding

that is normally attributed to this relationship, except that it occurs between peers instead. In both of these excerpts, the participants engage in exploratory talk, that is, talk that is oriented toward ideas and content rather than the participants themselves.

In thinking about informal learning environments in this way, their refined role becomes that of a provider of the "It," and also a provider of space for the peer-peer scaffolding relationship. One special advantage these environments bring to this role, especially considering the case of well-funded museums, is that they have an overwhelming amount of resources to bring to the creation of this content. Premier informal institutions often implement staggering features. For example, in the California Academy of Sciences there can be found a glass tunnel that traverses a flooded rainforest ("Rainforests of the World | California Academy of Sciences," n.d.). The wonder of the "It" found in these institutions is rarely surpassed except by nature itself.

Limitations and critical reflection

In light of my chapter on designing informal learning environments, there are several limitations, and criticisms of the exhibit design and implementation that deserve mention. First, of course, is the influence that a research context has on the nature of interaction with the exhibit, as participants felt the need to vocalize their thoughts for the recording (Bell et al., 2009, p. 64). Whether this impacted the learning process is unknown. Another limitation is the lack of related exhibits and diverse modalities. This might have impacted learners' abilities to find relevance with the exhibit, and link their experiences to broader contexts.

The most important criticism I have of the Water Circuit in retrospect is its limited interactivity. There were really only three possible "moves" that participants could make with the exhibit, pouring water in one of two top buckets, or in both at the same time. While they could of

course pour water in any of the other two buckets, it would not yield behavior that was quite as rich. Many participants interacted with the exhibit in ways I hadn't anticipated. Some of those new interactions were insightful for participants, but in general, they ended up being forgettable interactions that happened during the course of trial and error experiments. From the perspective of enabling continued investment, every possible interaction that can happen with an exhibit should ideally be information rich, and help build on the learning experience.

Other observations

I found that having a title for the exhibit was very important. In the instances I tested the exhibit without a title, participants did not find meaning with their experiences that related to computers. By having a title, or introducing the exhibit within the frame of it being a circuit, this helped participants think of it in a different way.

7

REFLECTION ON CLASS LESSON

For the Capstone in-class lesson, my goal was to design a lesson based around the concept of informal learning. My understanding goals were epistemological and meta-cognitive in nature. I had defined two goals to inform my planning of the lesson:

- Understand how play as an important precursor to more complex understandings and development of expertise.
- Be able to accommodate play in thinking about learning.

I decided that I would assess understanding of goals based on responses given to a short reflective prompt at the end of the class:

- What is the role of play in learning?

While I was not completely satisfied with this form of assessment, I felt that with the limited time I had to teach the lesson (25 minutes) it was more important to maximize the time I had trying to teach for understanding than to assess the impact of my teaching. If this unit was to extend beyond just the one lesson, my approach would be much more assessment based. In this case, however, my knowledge of the effectiveness of my teaching would make no difference to the teaching I was doing, since I would not have any follow-up opportunities with this concept in the context of Capstone. I also compromised by not doing any sort of pre-post assessment; having access to their thinking about play and learning both pre- and post-lesson would have been more informative than just having the post-lesson responses.

As my goal was to get the class to reflect on informal learning, I decided that I needed to give them a powerful informal learning experience that could help them start to see their own learning in perhaps a new light. In order to do this, I decided to allocate the first 10 minutes of

the class to an informal learning experience in a new concept area. I chose the concept area that I have the most expertise in, computer science, and built a museum-style exhibit that centered on the concept of circuits and binary addition. I had been user testing this exhibit for the past month, and it was currently on its third iteration, so I had already ironed out a lot of the design kinks that impeded inquiry and engagement.

The nature of the class' experience with this exhibit was crucial in order for the reflective discussion, which would take place during the next 10 minutes of the class, to have resonance. Without a powerful experience for learners to reflect on, my lesson would fail. Therefore, I had to somehow quickly provide motivation for engagement, an informal context for investigatory play, and an understanding to be attained. I realized that I could not achieve these goals given the context of a classroom lesson within which this assignment was framed. This was the reasoning that led to my decision to simply not be present for 7 minutes while the class played with the exhibit. To abridge any time it might take for the class to figure out how to use the exhibit, and to guide their inquiry, I prefaced this play activity by giving the class a short explanation of what the exhibit was and how to use it, and by giving them a challenge ("You have 7 minutes to figure out how this works") to overcome. This aligns with Gee's (2004, p. 71) concept of challenge, in that a challenge at the appropriate level serves multiple needs: it provides motivation for engaging with that challenge, and satisfaction when the challenge is overcome, i.e. when understanding is reached. Then I left them to it.

I considered the crux of my lesson to be the reflective discussion that would occur after this experience with the exhibit. I wanted the class to think about the experience they just had, in terms of what understandings they gained and the manner in which they reached them (i.e. inquiry within an informal context), and how that compared or contrasted to their own view of how they learned, and what learning in general is. I decided that a short writing activity might be

a good way to help the class begin to flesh out their own personal views on learning. I asked them to write a short response to the questions:

- What is something that you know or can do really well?
- What experiences contributed to you getting to that level?

I then handed out a short quote that argued for a specific view of learning (diSessa, 2001, pp. 77-79):

> From the outside, I looked "smart." I learned quickly and more deeply that most. When I got to college, I became famous, if not notorious, among my friends for having a superb intuitive feel for what we were learning in physics. I could guess answers and make good judgments about how things should turn out....I could think about problems in ways that weren't instructed, but it was not native intelligence alone, if at all, that accounted for my success. It was a strong intuitive foundation built in electronics play. There's an important little lesson in the midst of this narrative. Hidden knowledge, such as knowledge in forms we aren't used to recognizing, is frequently assigned to the category of "intelligence."

I hoped that the process of reflecting on these questions, and then reacting to the quotation's claims, would provide the seeds for a good discussion. I saw my role as a teacher in this discussion as being a maximizer of sharing, i.e. as trying to expose the class to each others' understandings about learning, and to then bring out the common threads that existed between those understandings, with a special emphasis on any newly forming understandings that were being shaped by the recent experience with the water circuit exhibit. Some questions I had prepared for this discussion were:

- Are there similarities between your reflection, the exhibit experience, and this quote?
- Are there differences? What are they?
- This quote and the exhibit are after a distinct view of learning, and your personal anecdote may be about a different kind of learning. Does your position disagree? Why?

In essence, I was trying to bring about meta-cognitive exploratory talk. In retrospect, I wonder how Wegerif's (2008, p. 279) concept of exploratory talk, in which the object of talk is on ideas and not persons, works when the topic of discourse is a reflective one, and therefore necessarily personal. From an understanding perspective, I had hoped that I might provide a

learning experience (the exhibit) that did not fit within some theoretical or epistemological ideas that the class might have had. Essentially, I was going after a sort of meta-cognitive disequilibrium. I reasoned that the act of writing and engagement in discourse would spur a kind of meta-cognitive thinking that brought implicit epistemological views to the surface, and exposed them to the input of others, myself, and the present context of discussion.

Here is a general outline taken from my notes as to the order and structure of the lesson:

- Bring class outside, introduce class to the exhibit, how it works, what it is
- Give them a challenge, and then leave: Figure out how it works, and why it works the way it does
- Come back in 7 minutes, bring them upstairs
- Explain purpose of that exercise, how it's a sub-purpose for gaining a learning experience to reflect on
- Have class write down responses to the first prompt
- Reflective discussion, based on their learning experiences, written reflections, and thoughts on the diSessa quote
- Have class write down responses to the second prompt

Here is a summary of the feedback I received on this lesson:

> **Positive feedback**
> The social nature of playing with the exhibit meant that individuals had the ability to both interact with the exhibit, and watch others interact with the exhibit. These multiple modes of engagement helped for achieving understanding.
>
> Having a physical object served as tool to help aid in understanding. Interacting with the physical object enabled individuals to apply what they understood about it. Similarly, some of the benefits normally received from dialogue could also be felt by, essentially, a physical dialogue: watching someone else play with the exhibit, or trying to work it together with someone else.
>
> **Critical feedback**
> There was some confusion over the exact understanding objective, i.e. what I was asking the class to do, which robbed time away from the activity.
>
> My framing of the exhibit as a calculator activated certain prior knowledge that ended up being a barrier to understanding. However, this framing was also useful for understanding the broader context of the exhibit.
>
> The detail of the exhibit-based learning experience was very powerful, whereas the reflective activity wasn't as detailed, so there was not as close a link to be made between the experience with the exhibit and the reflection piece. Basically, the exhibit experience

was very specific, whereas the reflection was very general, therefore the first experience was more powerful.

Suggestions

There was confusion as to why we were bringing in other things that we were good at (reflective prompt), when we had just had a relevant experience with the exhibit. It might have been more useful instead to focus on understandings that were reached about the machine, because all members of the class could have brought different things to that.

It would have been useful for the class to reflect on their experiences with the model.

In light of this feedback, I would make several refinements to the lesson if I was to teach it again. I would pay even more close attention to language I used to introduce the exhibit. The connection I drew to calculators was useful, but also presented some issues. In this case some members of the group did not struggle with this connection, and were able to help those who did, and I think in most cases the effect of group talk would remedy small issues like this. However, it is something important to be aware of how I, as a teacher, frame knowledge, activities, and objectives.

In the reflective writing activity and the class discussion, I would do much more to incorporate and leverage the experience that the class just had with the exhibit. This turned out to be a powerful experience for all involved, and I think that I did not make as much use of that experience as I could have, instead diverting the class' focus toward less immediately felt past experiences. I still would want to tap into the class' implicit epistemologies and views on learning however. Maybe one way to do this would be to reflect on how they think their experience with the exhibit could inform their future learning in that content area?

My opening question for discussion turned out to be initially confusing to the class, because there were so many elements to it (compare and contrast three separate things). I was prepared for the blank stares that can often follow a teacher's question, but nonetheless I think this question was a bit too complex for it to be the first one asked, even if it came right after a

reflective writing activity.

Finally, I think that if I made the reflective writing activity more about the exhibit experience, it could serve a dual role as an assessment tool. This would require a very elegant prompt—which I have not yet come up with—but by embedding the assessment more naturally within the lesson, this would allow the class to spend more time in discussion.

CONCLUSION

Throughout this portfolio, I have argued for a conception of thinking, understanding, and learning that sheds light on why informal learning environments are effective sources of education and what is unique about their educational role. We use thinking as a way of working on understandings, which in turn are accumulated in the pursuit of learning within a domain. As thinking is a process of encountering new artifacts and building meaning with them in situated contexts, we can see that informal learning environments serve this model of thinking through their ability to create settings that push learners to think by way of exposure to a diverse and multi-modal array of artifacts. Similarly, in consideration of a performance view of understanding, we can see that informal learning environments provide plenty of opportunities to practice and master understanding performances. Most importantly, informal learning environments excel at supporting the continued pursuit of learning by giving people the kinds of experiences that create, as Oppenheimer (1976) called them, people who are addicted to learning.

While the museum model has the potential to engage and support learners in these ways, designing a museum environment that lives up to this potential is a formidable task. I detailed a design approach to informal learning environments that attempts to honor and leverage our knowledge of how people think, understand, and learn. In support of this design approach, I provided real-world examples from my own work to help expose the process of design and refinement of informal learning experiences.

As I wrote in the beginning of this portfolio, it is an exciting time to be a learner. There is a growing plethora of opportunities and resources for exploring almost every curiosity imaginable, and in many pockets of our culture, our approach to and perception of learning is

being reworked in favor of experiences that are non-evaluative, playful and leisure-based, and unique to individual preferences. These new learning opportunities take many forms. I have focused specifically on informal learning environments in the hopes that more people, by embracing the view that much valuable learning occurs informally and through play, and that our natural tendencies toward play and exploration can be leveraged to create dynamic and engaging learning environments, can realize their value as educational resources.

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POSTSCRIPT

I think the most interesting aspect of working on this project was the difficulty marrying what was a cyclical process of thinking and idea generation, with a linear process of production. Given that the concepts of thinking, understanding, learning, and teaching are so heavily intertwined, my development and refinement of each separate concept necessarily resulted in a rethinking and maturation of the other concepts. For example, when I started to develop my theory of learning, this necessarily impacted my theories of thinking and understanding. However, since I wrote my portfolio sequentially, and because our readings were somewhat thematically sequenced as well, it felt very hard to keep my previous writings up to date with the new ideas I was having, and even more importantly, I felt it was almost impossible to keep the design of my exhibit up to date with these ideas. This tension, while difficult to address, was a positive one. The push to continuously ensure a horizontal alignment of my ideas kept the bigger picture of education in my head at all times. Without this pull toward the bigger picture, I think I would have become lost in specificity. Additionally, by constantly finding criticisms in my previous work, it was made very apparent the growth that I was experiencing in terms of my thoughts on education.

Sharing my progress, and sharing others' progress, within this class community was very helpful for my thinking process. Hearing the viewpoints and reactions that the class had about my ideas was particularly valuable, primarily because when people pointed out their own confusions interpreting my writing, that exposed me to the areas of thought that I had not fully clarified for myself, and needed to spend more work on. Also, the process of interpreting, critiquing, and giving feedback on the work of my peers helped me articulate a lot of ideas for

myself that were previously unarticulated. This helped me translate a lot of my thinking into a communicable form.